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ABSTRACT

Designed to improve student achievement in reading, language arts, and mathematics, the computer-assisted instruction (CAI) program in the Newark, New Jersey, schools comprises a regular component for remedial and average-achieving students, an enrichment component for higher achieving students, and a bilingual component for students having limited proficiency in English. An evaluation of the program's effectiveness showed that: (1) the regular CAI program for mathematics and reading was more beneficial for students qualifying for remedial services than for average achievers; (2) the most effective management strategies were affective encouragement in reading and coordinated instruction in mathematics; (3) elementary students in the enrichment program scored higher in vocabulary but not in reading comprehension than nonparticipants; (4) students in the mathematics enrichment program scored higher than nonparticipants in both math computation and concepts and applications; (5) ninth grade algebra students in the program scored higher than nonparticipants in math computation but not in concepts and applications; (6) students in the bilingual program who were initially the most proficient in English had the smallest returns, but spent the most time on the computer; (7) the reading comprehension component was more effective for sixth grade students than for fourth and fifth graders; (8) CAI-developed skills in English proficiency at the primary level seemed to have no effect on academic achievement; and (9) participation in the CAI program did not significantly assist the performance of students in the upper grades in either English proficiency or mathematics. Six recommendations based on these findings conclude the report. The text is supplemented by 76 tables and 6 appendices that include 2 extensive companion studies: (1) "Reading Competencies and Reading Comprehension"; and (2) "The Impact of Computer-Assisted Instruction on Mathematics Learning Gains of Elementary and Secondary Students." (EW)

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COMPUTER-ASSISTED INSTRUCTION

EVALUATION REPORT

1983 - 1984 SCHOOL YEAR

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PREFACE

The Newark School District is the largest in the State of New Jersey and ranks among one of the twenty-five largest in the nation. Like other urban school districts, Newark faces numerous problems affecting students' performance, many of which have been recurring for several years. The Board of Education recognized the need for an Office of Research and Evaluation in order to address some of these problems in a systematic way and to improve student achievement.

As a result of the commitment to improve the educational opportunities of disadvantaged students in Newark, the Victoria Foundation provided "seed monies" to establish the Office of Research and Evaluation. Due to a reorganization at the Central Office, the Office of Research and Evaluation became known as the Division of Research, Evaluation and Testing (DRET) as it assumed the responsibility for district-wide testing. The goal of the Division remains that of improving student achievement and personal growth in a cost-effective manner through:

a. Assessing student performance by the administration of valid and reliable tests;

b. Evaluating the effectiveness of ongoing educational programs; and

c. Tying the results of research, evaluation, and testing to program modification and improvement.

The total of the Division is thus congruent with the Foundation's deepest commitment to "enrich the learning experiences of those at the bottom of the ladder for reasons beyond their control."

With this goal in mind, the Division of Research, Evaluation and Testing is currently undertaking a number of projects, a major one being the evaluation of the effectiveness of computer-assisted instruction.

We are therefore very grateful to the Victoria Foundation for its role in developing the Board of Education's internal capability to evaluate its programs and for the Foundation's sincere commitment to improve educational opportunities for students in the Newark School District.

Dr. Gene A. Foti
Acting Executive Superintendent

Table of Contents

	Page
Acknowledgements	i
Preface	ii
Table of Contents	iv
List of Tables	viii
CHAPTER 1 - Introduction	1
1.1 Overview of the Program	1
1.1.1 The Nature of Computer-assisted Instruction.	1
1.1.2 Equipment	3
1.1.3 The Newark CAI Program	4
1.2 Summary of Findings	5
1.2.1 The Regular CAI Program in Reading	5
1.2.2 The Regular CAI program in Mathematics	6
1.2.3 The Enrichment CAI Program	6
1.2.4 The Bilingual CAI Program	7
1.2.5 Companion Study: Reading Competencies and Reading Comprehension	8
1.2.6 Companion Study: The Impact of Computer-assisted Instruction on Mathematics Learning	9
1.3 Organization of Report	10
CHAPTER 2 - The Regular CAI Program in Reading	11
2.1 Project Narrative	11
2.1.1 Introduction and Objectives	11
2.1.2 Selection of Students	11
2.1.3 Staff	12
2.1.4 Educational Setting	13
2.1.5 Computer Hardware	14
2.1.6 Activities and Materials	14
2.2 Project Evaluation - Overview	16
2.2.1 Evaluation Design	16
2.3 Project Evaluation - Grades 2 and 3	19
2.3.1 Findings (Nonremedial Students)	19
2.3.2 Findings (Remedial Students)	20
2.4 Project Evaluation - Grades 4 and 5	21
2.4.1 Findings (Nonremedial Students).	21
2.4.2 Findings (Remedial Students)	22
2.5 Project Evaluation - Grade 6	24
2.5.1 Findings (Nonremedial Students)	24
2.5.2 Findings (Remedial Students)	26

	Page
2.6 Project Evaluation - Grades 7 and 8	29
2.6.1 Findings (Nonremedial Students)	29
2.6.2 Findings (Remedial Students)	30
2.7 Project Evaluation - Grade 9	32
2.7.1 Findings (Remedial Students)	32
2.8 CAI Management Characteristics and Achievement	35
2.8.1 Overview	35
2.8.2 Evaluation Design	36
2.9 Project Evaluation - CAI Management Characteristics and Reading Achievement (Grades 4-8)	37
2.9.1 Findings (Remedial Students)	37
2.10 Conclusions and Recommendations	39
CHAPTER 3 - The Regular CAI Program in Mathematics	43
3.1 Project Narrative	43
3.1.1 Introduction and Objective	43
3.1.2 Selection of Students	43
3.1.3 Staff	44
3.1.4 Educational Setting	45
3.1.5 Computer Hardware	45
3.1.6 Activities and Materials	46
3.2 Project Evaluation - Overview	47
3.2.1 Evaluation Design	47
3.3 Project Evaluation - Grades 2 and 3	49
3.3.1 Findings (Nonremedial Students)	49
3.3.2 Findings (Remedial Students)	50
3.4 Project Evaluation - Grades 4 and 5	51
3.4.1 Findings (Nonremedial Students)	51
3.4.2 Findings (Remedial Students)	54
3.5 Project Evaluation - Grade 6	56
3.5.1 Findings (Nonremedial Students)	56
3.5.2 Findings (Remedial Students)	59
3.6 Program Evaluation - Grades 7 and 8	62
3.6.1 Findings (Nonremedial Students)	62
3.6.2 Findings (Remedial Students)	63
3.7 Project Evaluation - Grades 9-12	64
3.7.1 Findings (Nonremedial Students)	64
3.7.2 Findings (Remedial Students)	66
3.8 Project Evaluation - Special Education	69
3.8.1 Findings	69
3.9 CAI Management Characteristics and Achievement	69
3.9.1 Overview	69
3.9.2 Teacher Comments About CAI Management	70
3.9.3 Evaluation Design	71

Page

3.10 Project Evaluation - CAI Management Characteristics and Mathematics Achievement 73
3.10.1 Findings (Grades 4-8 Remedial Students) 73
3.10.2 Findings (Grades 9-12 Remedial Students). . . . 75
3.11 Conclusions and Recommendations 77

CHAPTER 4 - The Enrichment CAI Program 81

4.1 Project Narrative 81
4.1.1 Introduction and Objectives 81
4.1.2 Selection of Students/Staff/Activities 83
4.1.2.1 Lafayette Street School 83
4.1.2.2 Elliott Street 84
4.1.2.3 Bergen Street and Cleveland School 84
4.1.2.4 Avon Avenue School. 85
4.1.2.5 Barringer Prep. 86
4.2 Project Evaluation 86
4.2.1 Evaluation Design 86
4.2.2 Results: Critical Reading Skills (CRS). 87
4.2.3 Results: Mathematics Enrichment Modules, Grades 7 & 8 (EM) 89
4.2.4 Results: Introduction to Algebra (ALG). 92
4.2.5 Conclusions and Recommendations. 93

CHAPTER 5 - Bilingual CAI Program 95

5.1 Project Narrative 95
5.1.1 Introduction and Objectives 95
5.1.2 Selection of Students 96
5.1.3 Program Structure 96
5.1.4 Staffing 98
5.2 Project Evaluation 99
5.2.1 Program Effectiveness 99
5.2.2 Program Efficiency 100
5.2.3 Skills Transfer 100
5.3 Evaluation Technique 101
5.3.1 Evaluation Design 101
5.3.2 Findings - Communication Skills 102
5.3.2.1 Primary Grades 102
5.3.2.2 Intermediate Grades 105
5.3.2.3 Advanced Elementary Grades 108
5.3.2.4 High School 109

APPENDIX A - Evaluation Models 111

APPENDIX B - Comprehensive Tests of Basic Skills 114

Page

APPENDIX C - Description of Computer-Assisted Instruction (CAI) Curriculum Used in the Newark School System 117

APPENDIX D - Glossary of Terms 121

APPENDIX E - Companion Study: Reading Competencies and Reading Comprehension 124

APPENDIX F - Companion Study: The Impact of Computer-Assisted Instruction on Mathematics Learning Gains of Elementary and Secondary Students . . . 155

List of Tables

Table		Page
2.1	CTBS Level, Form, and Remedial Cutoff Scores for Each Grade in the Regular CAI Program in Reading . . .	18
2.2	Pre- and Posttest Mean Reading Scores (NCE), Grades 2 and 3 (Nonremedial)	19
2.3	Analysis of Covariance of Effects of the CAI Program on Reading Achievement, Grades 2 and 3 (Nonremedial)	20
2.4	Pre- and Posttest Mean Reading Scores (NCE), Grades 2 and 3 (Remedial)	20
2.5	Pre- and Posttest Mean Reading Scores (NCE) Grades 2 and 3 (Nonremedial)	21
2.6	Analysis of Covariance of Effects of CAI Program on Reading Achievement, Grades 4 and 5 (Non-remedial)	22
2.7	Pre- and Posttest Mean Reading Scores (NCE) Grades 4 and 5 (Remedial)	23
2.8	Analysis of Variance of Effects of the CAI Program on Reading Achievement, Grades 4 and 5 (Remedial)	24
2.9	Pre- and Posttest Mean Reading Scores (NCE) Grade 6 (Nonremedial)	25
2.10	Analysis of Covariance of Effects of the CAI Program on Reading Achievement, Grade 6 (Nonremedial)	25
2.11	Pre- and Posttest Mean Language Scores (NCE), Grade 6 (Remedial)	26
2.12	Pre- and Posttest Mean Reading Scores (NCE), Grade 6 (Remedial)	27
2.13	Multiple Regression of Effects of the CAI Program on Reading Achievement, Grade 6 (Remedial, Full Year CAI Only)	28
2.14	Pre- and Posttest Mean Language Scores (NCE), Grade 6 (Remedial)	28
2.15	Pre- and Posttest Mean Reading Scores (NCE), Grades 7 and 8 (Nonremedial)	29

Table		Page
2.17	Pre- and Posttest Mean Reading Scores (NCE), Grades 7 and 8 (Remedial)	31
2.18	Analysis of Covariance of Effects of the CAI Program on Reading Achievement, Grades 7 and 8 (Remedial)	31
2.19	Pre- and Posttest Mean Reading Scores (NCE), Grade 9 (Remedial)	33
2.20	Analysis of Covariance of Effects of the CAI Program on Reading Achievement, Grade 9 (Remedial)	33
2.21	Pre- and Posttest Mean Language Expression Scores (NCE) Grade 9 (Remedial)	34
2.22	Analysis of Variance of Effect of the CAI Program on Language Expression Achievement, Grade 9 (Remedial)	35
2.23	Pre- and Posttest Mean Reading Scores (NCE), CAI Management Groups (Grades 4-8 Remedial)	37
2.24	Analysis of Covariance of Effects of CAI Management Characteristics on Reading Achievement (Grades 4-8 Remedial)	38
3.1	CTBS Level, Form, and Remedial Cutoff Scores for Each Grade in the Regular CAI Program in Mathematics	48
3.2	Pre- and Posttest Mean Mathematics Scores (NCE), Grades 2 and 3 (Nonremedial)	49
3.3	Analysis of Covariance of Effects of the CAI Program on Mathematics Achievement, Grades 2 and 3 (Nonremedial)	50
3.4	Pre- and Posttest Mean Mathematics Scores (NCE), Grades 2 and 3 (Remedial)	51
3.5	Pre- and Posttest Mean Mathematics Scores (NCE), Grades 4 and 5 (Nonremedial)	51
3.6	Analysis of Covariance of Effects of the CAI Program on Mathematics Achievement, Grades 4 and 5 (Nonremedial)	52

Table		Page
3.7	Pre- and Posttest Mean Math Concepts and Applications Scores (NCE), Grades 4 and 5 Problem Solving (Nonremedial)	53
3.8	Analysis of Covariance of Effects of the CAI Program on Math Concepts Applications Achievement, Grades 4 and 5 Problem Solving (Nonremedial)	53
3.9	Pre- and Posttest Mean Mathematics Scores (NCE), Grades 4 and 5 (Remedial)	54
3.10	Analysis of Covariance of Effects of the CAI Program on Grades 4 and 5 Mathematics Achievement (Remedial)	55
3.11	Pre- and Posttest Mean Math Concepts and Applications Scores (NCE), Grades 4 and 5 Problem Solving (Remedial)	55
3.12	Analysis of Covariance of Effects of the CAI Program on Math Concepts and Applications Achievement, Grades 4 and 5 Problem Solving (Remedial)	56
3.13	Pre- and Posttest Mean Mathematics Scores (NCE), Grade 6 (Nonremedial)	57
3.14	Analysis of Covariance of Effects of the CAI Program on Mathematics Achievement, Grade 6 (Nonremedial)	57
3.15	Pre- and Posttest Mean Math Concepts and Applications Scores (NCE), Grade 6 Problem Solving (Nonremedial)	58
3.16	Analysis of Covariance of Effects of the CAI Program on Math Concepts and Applications Achievement, Grade 6 Problem Solving (Non-remedial)	58
3.17	Pre and Posttest Mean Mathematics Scores (NCE) Grade 6 (Remedial)	59
3.18	Analysis of Covariance of Effects of the CAI Program on Mathematics Achievement, Grade 6 (Remedial)	60

Table		Page
3.19	Pre- and Posttest Mean Math Concepts and Applications Scores (NCE), Grade 6 Problem Solving (Remedial)	60
3.20	Analysis of Covariance of Effects of the CAI Program on Math Concepts and Applications Achievement, Grade 6 Problem Solving (Remedial) . . .	61
3.21	Pre- and Posttest Mean Mathematics Scores (NCE), Grades 7 and 8 (Nonremedial)	62
3.22	Analysis of Covariance of Effects of the CAI Program on Mathematics Achievement, Grades 7 and 8 (Nonremedial)	63
3.23	Pre- and Posttest Mean Mathematics Scores (NCE), Grades 7 and 8 (Remedial)	63
3.24	Analysis of Covariance of Effects of the CAI Program on Mathematics Achievement, Grades 7 and 8 (Remedial)	64
3.25	Pre- and Posttest Mean Mathematics Scores (NCE), Grades 9-12 (Nonremedial)	65
3.26	Analysis of Covariance of Effects of the CAI Program on Mathematics Achievement, Grades 9-12 (Nonremedial)	65
3.27	Pre- and Posttest Mean Math Concepts and Applications Scores (NCE), Grades 9-12 Problem Solving (Nonremedial)	66
3.28	Pre- and Posttest Mean Mathematics Scores (NCE), Grades 9-12 (Remedial)	67
3.29	Analysis of Covariance of Effects of the CAI Program on Mathematics Achievement, Grades 9-12 (Remedial)	67
3.30	Pre- Posttest Mean Math Concepts and Applications Scores (NCE), Grades 9-12 Problem Solving Remedial)	68
3.31	Analysis of Covariance of Effect of the CAI Program on Math Concepts and Applications Achievement, Grades 9-12 Problem Solving (Remedial)	68

Table		Page
3.32	Pre- and Posttest Mean Mathematics Scores (NCE), CAI Management Groups (Grades 4-8 Remedial)	73
3.33	Analysis of Covariance of Effects of CAI Management Characteristics on Mathematics Achievement (Grades 4-8 Remedial)	74
3.34	Pre- and Posttest Mean Mathematics Scores (NCE), CAI Management Groups (Grades 9-12 Remedial)	76
3.35	Analysis of Covariance of Effects of CAI Management Characteristics on Mathematics Achievement (Grades 9-12 Remedial)	76
4.1	Pre & Posttest Mean NCE Scores of CTBS Reading Subtests: CRS Students and Non-CAI Students	88
4.2	ANCOVA Summary Table: Vocabulary	89
4.3	ANCOVA Summary Table: Reading Comprehension	89
4.4	Pre and Posttest Mean Scores of CTBS Mathematics Subtests: EM Students and Non-CAI Students	90
4.5	ANCOVA Summary Table: Computation	91
4.6	ANCOVA Summary Table: Concepts & Applications	91
4.7	Pre and Posttest NCE Scores of Algebra Students on Mathematics Subtests	92
5.1	Enrollment of LEP Students Participating in the CAI Program	97
5.2	Regression of 1984 LAB Scores on CAI Participation	102
5.3	Regression of 1984 LAB Scores on Time Investment in CAI	104
5.4	Regression of CTBS/E Scores on Time Investment in CAI	104
5.5	Regression of 1984 LAB Scores on CAI Participation	105
5.6	Regression of 1984 LAB Scores on Time Investment in CAI	107

Table		Page
5.7	Regression of CTBS/E Scores on Time Investment in CAI	107
5.8	Regression of 1984 LAB Scores on CAI Participation	108
5.9	Regression of 1984 LAB Scores on CAI Participation	109
5.10	Regression of CTBS/E Total Math Score on CAI Participation	110

CHAPTER 1

INTRODUCTION

1.1 Overview of the Program

1.1.1 The Nature of Computer-assisted Instruction

Individualization of instruction has long been a primary concern in education. With increasing advances in technology, computer-assisted instruction (CAI) is now seen by many as a method of providing individualized instruction to large numbers of students. There are several interrelated purposes which computer-assisted instruction may serve. First, CAI can provide intensive practice and reinforcement of specific skills, with immediate feedback to the learner. Second, by providing instruction tailored to individual needs, CAI can make maximum use of limited resources, both in terms of instructor attention and student time on needed tasks. Finally, CAI can present educational material in a format designed to maintain the student's interest and attention.

There are a number of different approaches to the use of computers in education. A useful classification of these approaches was formulated by K. Goldberg and R. Sherwood (Microcomputers: A Parent's Guide, Wiley, 1983). Three of these categories which are particularly relevant are the following:

1. Learning from computers. This category encompasses approaches to computer-assisted instruction in which the computer is used as a means for transmitting specific subject matter, such as reading and math. The flow of information is exclusively or primarily from the computer to the student, with the computer presenting material or exercises and the student

responding. The computer retains records of the student's progress through the curriculum. There are three levels of computer-assisted instruction, based on the degree of interaction between student and computer:

a. Drill and practice: The computer provides the student with exercises which reinforce the learning of specific skills taught in the classroom, and supplies immediate feedback as to the correctness of each response. CAI used in this manner functions as a supplement to regular classroom instruction, and may be especially useful when a teacher does not have the time to work individually with each student. Drill and practice on the computer may also motivate students more than do traditional workbook exercises.

b. Tutorial: Tutorial CAI provides some information or clarifies certain concepts in addition to providing the student with practice exercises. In this sense the computer begins to take over actual instructional functions, tailored to the student's individual level of competence.

c. Dialogue: At this level the student takes an active role in interacting with the computer, giving instructions in the form of a computer language in order to structure his or her own curriculum. The computer provides information, exercises and feedback. Dialogue CAI comes the closest to actually substituting for regular instruction.

2. Learning about computers. This category represents what is commonly known as computer literacy. Though there is some disagreement as to what skills computer literacy should entail, most practitioners in the field believe it should include some knowledge of the components of a computer system, the basic operation of a computer, the impact of computers on society, and an introduction to actual programming. In this case the computer is not the means for transmitting information relevant to other academic subjects, but is the object of study itself. Thus computer literacy differs substantially from CAI and need not be involved in CAI at all.

3. Learning about thinking with computers. In this category, the computer serves not to impart specific content but as a tool for developing thinking skills. The programming language LOGO, developed by Seymour

Papert and his colleagues at the Massachusetts Institute of Technology, is a popular example: Students using LOGO learn, through their own programming experiences, methods for thinking through and solving problems. While LOGO may involve, directly or indirectly, skills related to mathematics, it does not teach mathematics content, but rather, problem solving processes.

When planning educational programs involving computers or comparing the value of these differing approaches to the use of computers in education, it is important that the program be designed to accomplish clearly defined goals. No one approach is inherently better than the others; the objective of teaching specific reading and math skills, for example, cannot be met by a program which is designed to teach computer literacy. Thus it is vital, when planning or evaluating a computer-aided instructional program, to consider it in light of its desired purpose; only then can the program be judged appropriate or valuable.

1.1.2 Equipment

Computer equipment falls into two categories: hardware and software. Computer hardware refers to the machines themselves; computer software represents the programs or courses which are run on the computer and are stored in the computer on tape or disk.

There are two types of computer hardware typically used in providing computer-assisted instruction. The first, the microcomputer, is a very small, independently functioning computer which can fit on a tabletop. It is completely self-sufficient and need not be connected to a larger computer. An example, found in some Newark schools, is the Commodore PET. The other type, the terminal, has been more frequently used in Newark. A terminal cannot function independently, but must be connected to a larger

computer (either a main-frame or a minicomputer). Frequently this connection is made by means of a telephone line; such a terminal is called a modem. Both the microcomputer and the terminal have their advantages and disadvantages. The microcomputer, because it is self-sufficient and does not utilize a telephone line, can be less expensive to run than a terminal connecting to a main computer. On the other hand, most microcomputers have a limited memory capacity; terminals connected to a large computer, with more storage capacity, may have more flexibility in the programs or courses which they can utilize. Again, the appropriate choice is determined by the needs which the CAI program is to serve.

1.1.3 The Newark CAI Program

The Newark CAI program was designed to improve student achievement in the basic skill areas of reading, language arts, and mathematics. The program consists of three components: a regular component for remedial and average-achieving students, aimed at improvement of basic skills achievement; an enrichment component for high-achieving students and students who have completed the regular course material, teaching advanced topics in critical reading and mathematics; and a bilingual component for students having limited English proficiency, aimed at improvement of their English-language and basic mathematics skills.

The computer hardware and software (courses) used in the Newark CAI program are provided by the Computer Curriculum Corporation of Palo Alto, California. The hardware is in the form of terminals connected to a minicomputer by means of a telephone line; the courses cover various topics and levels of difficulty in the areas of reading (vocabulary and comprehension), language arts (mechanics and expression), and mathematics (computation and problem solving). Twelve schools, eight elementary and four high

schools, participate in one or more of the components of the program. In each school, computer work is supervised by either a teacher or a teacher aide; in some cases formal classroom instruction is provided along with the computer while in other cases the CAI is administered on a pull-out basis. The computer work is in the form of intensive drill and practice in the specific skill areas, in most cases administered for 20 minutes a day. A limited amount of tutorial work is also provided by some of the courses in the form of explanations of why students' answers are incorrect, with the invitation to try again. Approximately 1100 Newark students, 500 elementary and 600 high school students, received some computer-assisted instruction during the 1983-84 school year.

1.2 Summary of Findings

1.2.1 The Regular CAI Program in Reading

1. Overall, the regular CAI program in reading was more beneficial for students qualifying for remedial services than for students of average achievement. Gains in reading achievement were found for grades 2 and 3 (remedial only), grades 4 and 5 (remedial only), grade 6 (remedial and nonremedial), and grades 7 and 8 (remedial only). Gains in language arts achievement were found for grade 6 (remedial and nonremedial) and grade 9 (remedial).

2. Comparison of three different instructional management strategies used to administer the CAI to remedial elementary students (CAI in the context of formal, coordinated instruction; CAI in the context of extended solitary practice; CAI in the context of affective encouragement for good performance) showed affective encouragement to be the most effective of the

three strategies for enhancing reading achievement. This suggests the presence of a strong motivational factor in reading achievement. Coordinated instruction was superior to extended solitary practice for reading comprehension but not for vocabulary, suggesting the need for formal instruction combined with individual computer work for material strongly conceptual in nature.

1.2.2 The Regular CAI Program in Mathematics

1. The regular CAI program in mathematics, like the program in reading, appeared to be more beneficial for students qualifying for remedial services than for students of average achievement. Gains in mathematics achievement were found for grades 2 and 3 (remedial only), grades 4 and 5 (remedial only), grade 6 (both remedial and nonremedial) grades 9-12 (remedial only), and a small group of special education students.

2. Comparison of three different instructional management strategies used to administer the CAI to remedial elementary students (formal, coordinated instruction; extended solitary practice; and affective encouragement) showed that for mathematics achievement, coordinated instruction was the most effective strategy, followed by affective encouragement and, lastly, solitary practice.

3. Comparison of two management strategies used to administer the CAI to remedial secondary students (formal, coordinated instruction and solitary practice) showed coordinated instruction to be the more effective strategy for math computation only, with no difference for math concepts and applications.

1.2.3 The Enrichment CAI Program

1. Elementary students of above-average achievement enrolled in Critical Reading Skills (an advanced reading course) scored higher than a

comparison group of nonparticipants in vocabulary but not in reading comprehension.

2. Elementary students of above-average achievement enrolled in Math Enrichment modules (advanced special topics in mathematics) scored higher than the comparison group in both math computation and concepts and applications.

3. Ninth grade algebra students scored higher than the comparison group in math computation but not in concepts and applications.

1.2.4 The Bilingual CAI Program

1. In grades 4, 5, and 6, the students who received CAI scored more than 6 NCE points higher on the LAB than did those pupils who were not part of the program. But the students initially most proficient in English, though they spend the most time on the computer, had the smallest returns.

2. The Reading Comprehension component of the CAI curriculum may be the least useful to fourth and fifth graders, but the most relevant for sixth grade instruction.

3. At the primary level, the skills developed through CAI are limited to English proficiency and do not seem to lead to gains in overall academic standing.

4. In the upper grades (7 through 9), participation in the CAI program did not significantly help student performance in either English proficiency (LAB) or mathematics (CTBS/E).

1.2.5 Companion Study: Reading Competencies and Reading Comprehension

This study examined the relative development of several different types of reading skills and factors related to students' rate of progress in reading. Major findings were the following:

1. Of the skills that are traditionally assessed in reading comprehension subtests, the most difficult is interpretative comprehension. That is followed by vocabulary and paragraph understanding. Word attack and literal comprehension are the two areas where students show the greatest strength.

2. In terms of responsiveness to individualized instruction, students tend to show the largest gains in academic areas where they have already acquired some strength. The CAI curriculum seems particularly suitable for low-ability students in the areas of literal comprehension and paragraph interpretation. However, one needs to keep in mind that when an instructional program is made uniform for all students, responsiveness signals greater skill mastery but not necessarily greater competitiveness.

3. There is strong evidence that in order to facilitate the development of reading comprehension, there is an optimal order for introducing and reinforcing the various subskills. The order is as follows: word attack, literal comprehension, vocabulary, interpretive comprehension, and paragraph understanding. In his/her management of the reading class, a teacher is likely to get the best results if time is allocated to each strand in direct proportion to students' needs and to the strand's facilitative value.

4. Students' rate of progress in reading comprehension is related to their initial starting level, with lower-level students tending to make gains at a slightly faster rate than students beginning at higher levels.

This again points to the usefulness of CAI for remedial students in certain areas.

5. Students' rate of progress in reading comprehension bears some relationship to their prior strength in vocabulary skills; students with higher initial ability in this area tended to progress at a faster rate than students with lower initial ability.

6. Students' rate of progress was highest early in the program and tended to decline as their reading level advanced and the curriculum became more difficult.

1.2.6 Companion Study: The Impact of Computer-assisted Instruction on Mathematics Learning

This study examined the relationships of student attributes to mathematics achievement, the relative development of several different types of mathematics skills, and the impact of instructional management on achievement. Major findings were the following:

1. The coordination of instruction between the classroom and the computer program should be improved. Students would benefit if their strengths and weaknesses were dealt with in both places in a concerted effort.

2. Given that some skills are considered by Newark students to be more difficult than others, more time - more computer time and more classroom time - should be spent on these skills. Specifically, the more difficult skills are equations, measurement, fractions and decimals.

3. Second graders as a group seem to be too young to benefit greatly from CAI instruction, and higher ability third graders benefit more (in terms of CAI total gain scores) than lower ones. This suggests that second graders and lower ability third graders should probably not be instructed in math through CAI.

4. Whatever differences in performance that were found at the upper elementary and high school levels were in favor of lower ability students; thus, CAI seems to be a good remedial tool.

5. Teachers should supervise students on CAI. The computer does not tell a student why a mistake was made. Students benefit more when there is a dialogue between teachers and students.

6. Although boys did do better in problem solving skills (used only by upper elementary students), girls did as well as, if not better than, boys in all other skills. Computers do not differentiate between sexes. This should be a lesson for teachers and for girls, themselves. Math proficiency is probably not biologically predetermined.

1.3 Organization of Report

This evaluation report is organized into four major sections. Chapter 2 presents a description and evaluation of the regular CAI program in reading; Chapter 3 presents a description and evaluation of the regular CAI program in math. Chapter 4 describes and evaluates the effectiveness of enrichment CAI courses for high-achieving and advanced students. The final chapter, Chapter 5, presents a description and evaluation of the CAI program for bilingual students. Each chapter contains an overview of the program component, its objectives, the evaluation design employed, and the findings for that component. Results are analyzed for separate CAI course and, where appropriate, by grade level. Companion studies on CAI and reading and mathematics learning are presented in the Appendix.

CHAPTER 2

THE REGULAR CAI PROGRAM IN READING

2.1 Project Narrative

2.1.1 Introduction and Objectives

The Computer-assisted Instruction program provided supplementary individualized instruction in reading and, at some sites, language arts to students in grades 2 through 9 in eight selected Newark public schools. The program was based on the assumption that learning of specific skills can be accomplished most efficiently by regular and concentrated practice of those skills, in a format tailored to individual students' needs. Computers have the advantage of being able to provide individualized instruction for large numbers of students simultaneously, thus making maximum use of instructional time.

The CAI program's primary purpose is to provide students with intensive drill and practice in the basic skill areas of reading and language arts; in some cases, it has been used to facilitate the provision of compensatory educational services (Chapter I and State Compensatory Education services) as well. Students participating in the CAI program are expected to demonstrate significant educational progress in reading and language arts skills.

2.1.2 Selection of Students

Criteria for selection of students to participate in the CAI program varied widely from one school to another. At several sites, the CAI was used as a method of providing Chapter I or State Compensatory Education services. At two sites, students were selected for participation who

represented a wide range of achievement levels, in order to determine what type of students would benefit most from the program. In two elementary schools, younger students, mostly of above-average achievement, were chosen; at one of these sites this was done because it was felt that remedial students were already receiving other special services, while at the other site it was felt that low-achieving students in the past had not been able to benefit from the program. Thus the population of students receiving computer-assisted instruction is a varied one.

The number of students selected for participation in the CAI program varied from one site to another due to the variation in the number of terminals located at each school, from a low of 4 to a high of 8 at those sites at which reading instruction was offered. Approximately 440 students received computer-assisted instruction in reading and/or language arts during the 1983-84 school year.

2.1.3 Staff

The staff administering the CAI varied from school to school. At six sites the program was conducted by a teacher aide who supervised the activities of the students as they worked at the terminals, but who did not provide classroom instruction as part of the session. At the remaining two sites offering reading instruction, the CAI was administered by Chapter I teachers who integrated the individual computer sessions with actual classroom instruction.

The staff person in charge of administering the CAI was responsible for enrolling students in the computer courses, monitoring their progress by means of computer-generated reports, overseeing the computer sessions, and providing assistance when necessary. Beyond these minimal requirements, the actual role played by the CAI coordinator at each site varied

depending on the structure of the program at that site, the professional position of the coordinator, and the coordinator's personal style. Decisions regarding which courses in which to enroll the students were at some sites made by participants' regular classroom teachers and at others left to the CAI coordinator (teacher or teacher aide), the only restriction in the latter case being the sequence in which the courses were to be taken. Formal instruction was provided only by teachers; however, the degree of informal assistance provided by the teacher aides varied widely, with some merely watching students and answering specific questions, and others going around to individual students and providing extensive tutoring. Other practices also varied from one coordinator to another: Some teachers and aides provided varying degrees of positive reinforcement for achievement on the computer such as posting the names of high-scoring students each week and handing out little prizes and certificates for students finishing a unit; some also gave homework relating to the computer lessons in the form of worksheets generated from the computer or obtained elsewhere. Thus the management of the CAI sessions varied from one site to another, some of this variation being the result of the program at each site, some the result of the differing professional backgrounds of the staff, and much of it a function of the individual conducting the program.

2.1.4 Educational Setting

The setting in which the CAI was provided was largely a function of the format and staffing of the program at the individual site. At six sites, the CAI was administered in a separate room in which the terminals were set up (known as the computer room), in which no activities other than the CAI took place. At these sites, students received the CAI in a pull-out format administered by a teacher aide. At the two sites in which the

CAI functioned as an adjunct to the Chapter I instruction, the computer room also served as a classroom and students received a half-period of CAI combined with a half-period of classroom instruction provided by the Chapter I teacher.

2.1.5 Computer Hardware

Both the hardware and the software used in the CAI program are provided by the Computer Curriculum Corporation (CCC) of Palo Alto, California. A mini-computer is installed at the Board of Education; students work at modem terminals connected to this main computer. Terminals are provided by the company in groups of four; the number of terminals at each site varies from 4 to 8 for the program in reading. Each site is also supplied with one printer which is used to generate reports charting the students' progress. The two reports regularly obtained from the computer are course reports, listing students' current scores in each course, and monthly gain reports.

2.1.6 Activities and Materials

At most sites, students worked for approximately 20 minutes per day at the computer terminals. (At two sites, students were not sent to the terminals every day due to overcrowding; at one of these sites this problem was dealt with by dropping some students from the program, and at the other by extending the computer time to 40 minutes per session.) Ten minutes were spent on reading and ten on math. The computer courses consisted of intensive drill and practice in reading exercises, tailored to the individual's reading level. The first hour and forty minutes of computer work comprise initial placement, in which the level of difficulty of the exercises is adjusted upward and downward by the computer until it matches the student's level of proficiency. (The only exceptions to this rule are

the adult skills courses, used in the high schools, which contain no initial placement period.) After initial placement students' scores are recorded by the computer and are available from the computer-generated reports.

Four reading courses and two language arts courses were used in the regular CAI program. They are briefly described below; more detailed descriptions may be found in Appendix C.

Basic Reading (BR). The first of the reading courses, it consists of vocabulary, syntax, and literal and interpretive comprehension of simple sentences and paragraphs, aimed at the second-grade level.

Reading 3-6 (RD). This course provides exercises in the areas of word structure, vocabulary, literal and interpretive comprehension, and work-study skills, at grade levels 3 to 6. Passages are sentences rather than paragraphs.

Reading for Comprehension (RC). RC covers skills in the areas of word attack, vocabulary, literal and interpretive comprehension, work-study skills, and paragraphs, at grade levels 3 to 6.

Adult Reading Skills (ARS). ARS covers the same topics as RC; however, it is designed for remedial work with adults rather than for elementary students. It contains no initial placement period and can be worked through more rapidly than RC. It is used in the high schools only.

Language Arts 3-6 (LS). This course covers skills in language mechanics and expression such as capitalization, punctuation, parts of speech, sentence structure, and modifiers, at grade levels 3 to 6.

Fundamentals of English (FUN). This is a language expression course covering standard English usage of parts of speech and sentence structure. Though intended for students at the junior high school level and above who

require remediation in standard written English, it has been used with a small number of elementary-level students.

2.2 Project Evaluation - Overview

2.2.1 Evaluation Design

The objective of the regular CAI program in reading is to help participating students improve their reading achievement beyond the level that would be expected through the regular classroom instruction alone. The evaluation model used to determine whether this objective had been met was the analysis of covariance (ANCOVA). The analysis of covariance model compares the performance of program participants and the end of the year to that of a comparison group of nonparticipants, after adjustment for previous achievement level. This adjustment removes the effects of prior ability, leaving a purer measure of the effects of the program on achievement. If program participants then show a higher level of achievement at the end of the year than nonparticipants, the program may be said to have been effective in meeting the stated objective. (Further explanation of the analysis of covariance model may be found in Appendix A.)

Achievement prior to the CAI program was measured by the Comprehensive Tests of Basic Skills (CTBS), forms U and V, 1981, administered throughout the Newark School District in May 1983; achievement after the program was also measured by the CTBS, administered in May 1984. All CTBS scores were normal curve equivalents (NCE). The level and form of the CTBS administered to each grade are presented in Table 2.1. A comparison group of students not participating in the CAI program was chosen randomly from Newark's Student Information System, a computerized list of all students enrolled in the Newark School District; when feasible, these students were chosen from the same schools as those participating in the program. The

comparison group was chosen to be equivalent to participants in terms of grade and achievement levels.

Several subgroups of students were defined for the evaluation. Students were studied separately by grade, with adjacent grade levels combined; the grade level groups studied were grades 2 and 3, grades 4 and 5, grade 6, grades 7 and 8, and grade 9. This grouping was done because adjacent grades were frequently learning the same material and in order to avoid very small sample sizes.

Students taking any CAI reading course within each grade level were grouped together. This was done because all the reading courses had the same basic content, though the level of difficulty varied. Reading courses studied were Basic Reading, Reading 3-6, Reading for Comprehension, and for the ninth grade, Adult Reading Skills. Language Arts 3-6 students were studied separately. No students were included who had not progressed beyond the initial placement period (the first hour and forty minutes of computer time). Fundamentals of English, language expression course, was analyzed only for ninth grade students because no elementary students had progressed in it beyond initial placement.

Finally, students were grouped according to their achievement level as remedial and nonremedial students. Remedial students were defined as students scoring below the cutoff scores in Total Reading which normally establish eligibility for Chapter I services. Nonremedial students were those students scoring above the cutoffs. This distinction was made because the question had often been raised as to whether CAI was more effective for remedial or nonremedial students, and a number of sites were either using the remedial cutoffs as a criterion for selecting students, or were experimenting to find the answer to this question. Total Reading cutoff scores for each grade are presented in Table 2.1.

Table 2.1

CTBS Level, Form, and Remedial Cutoff Scores for Each Grade in the Regular CAI Program in Reading

Grade Level	Test Level & Form	Remedial Cutoff Score (NCE)
1	A,U	42
2	D,U	36
3	E,U	33
4	E,V	33
5	F,U	33
6	G,V	36
7	G,U	36
8	H,V	36
9	H,U	-

2.3 Project Evaluation - Grades 2 and 3

2.3.1 Findings (Nonremedial Students)

Forty-six students in grades 2 and 3 had taken one of the CAI courses in reading (Basic Reading, Reading 3-6, or Reading for Comprehension) and had both pre- and posttest CTBS scores available. Pre- and posttest mean reading scores in vocabulary and reading comprehension (in NCEs) for program participants and the comparison group are presented in Table 2.2. (The adjusted posttest means represented the means the two groups would have been expected to obtain had they been exactly equal to each other on the pretest; this controls for any initial differences between the groups.) It can be seen that both participants and nonparticipants declined in vocabulary and reading comprehension from pretest to posttest.

Table 2.2

Pre- and Posttest Mean Reading Scores (NCE), Grades 2 and 3 (Nonremedial)

Subtest	CAI[a] Pretest	CAI[a] Posttest Unadjusted	CAI[a] Posttest Adjusted	Non-CAI[b] Pretest	Non-CAI[b] Posttest Unadjusted	Non-CAI[b] Posttest Adjusted
Vocabulary	59.80	53.57	53.35	58.43	51.05	51.31
Reading Comprehension	60.04	48.72	47.72	54.40	49.13	50.28

[a] $n=46$
[b] $n=40$

The results of the analysis of covariance of the effects of the CAI program on grades 2 and 3 reading achievement are presented in Table 2.3. No significant effects of the program were found on achievement in either vocabulary or reading comprehension. Thus the program did not meet its objective for grade 2 and 3 nonremedial students.

Table 2.3

Analysis of Covariance of Effects of the CAI Program on Reading Achievement, Grades 2 and 3 (Nonremedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Vocabulary Pretest	1791.827	1	1791.827	9.286*
Program Participation	88.902	1	88.902	.461
Residual	16015.707	83	192.960	
Reading Comprehension Pretest	2499.748	1	2499.748	13.018**
Program Participation	135.530	1	135.530	.706
Residual	15937.828	83	192.022	

n=86
*$p < .005$
**$p < .001$

2.3.2 Findings (Remedial Students)

Only four grade 2 and 3 students eligible for remedial services had taken one of the CAI reading courses and had both pre- and posttest CTBS scores available. Their pre- and posttest means are presented in Table 2.4. It can be seen that these four students improved in both vocabulary and reading comprehension from pretest to posttest. Because of the small number of students in this category, no statistical tests of these means in comparison with nonparticipants could be performed.

Table 2.4

Pre- and Posttest Mean Reading Scores (NCE), Grades 2 and 3 (Remedial)

Subtest	Pretest	Posttest
Vocabulary	32.25	40.75
Reading Comprehension	24.75	43.50

n=4

2.4 Project Evaluation - Grades 4 and 5

2.4.1 Findings (Nonremedial Students)

Twenty-two nonremedial fourth and fifth grade students had taken one of the CAI reading courses and had both pre- and posttest vocabulary scores available; 27 students had both pre- and posttest reading comprehension scores available. Pre- and posttest mean reading scores, including adjusted posttest means, for these students and a comparison group of 24 nonparticipating students are presented in Table 2.5. Both CAI and non-CAI students declined somewhat in vocabulary from pretest to posttest. In reading comprehension, the CAI group improved somewhat (from a pretest mean of 36.48 to a posttest mean of 40.41) while the comparison group remained at approximately the same level.

Table 2.5

Pre- and Posttest Mean Reading Scores (NCE), Grades 2 and 3 (Nonremedial)

Subtest	CAI[a]			Non-CAI[b]		
	Pretest	Posttest		Pretest	Posttest	
		Unadjusted	Adjusted		Unadjusted	Adjusted
Vocabulary	48.55	47.95	47.55	45.61	43.00	43.37
Reading Comprehension	36.48	40.41	41.37	41.87	41.48	40.34

[a] n=22 (Vocabulary), n=27 (Reading Comprehension)

[b] n=24

The results of the analysis of covariance of the effects of the CAI program on reading achievement are presented in Table 2.6. Although participants had adjusted posttest means somewhat higher than nonparticipants in both vocabulary and reading comprehension, these differences failed to reach statistical significance. In the case of reading comprehension, the improvement in the CAI group mean was due to the progress of a

few individuals rather than the group as a whole; it is for this reason that the statistical analysis failed to show an overall significant effect on achievement for this group. Thus there is no evidence that the program had an overall beneficial effect on reading achievement for grade 4 and 5 nonremedial students, as compared with nonparticipants.

Table 2.6

Analysis of Covariance of Effects of CAI Program on Reading Achievement, Grades 4 and 5 (Nonremedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Vocabulary Pretest[a]	577.232	1	577.232	4.974*
Program Participation	197.740	1	197.740	1.704
Residual	4989.730	43	116.040	
Reading Comprehension Pretest[b]	405.128	1	405.128	3.858
Program Participation	11.652	1	11.652	.111
Residual	4935.703	47	105.234	

[a] $n=46$

[b] $n=50$

*$p < .05$

2.4.2 Findings (Remedial Students)

Thirty-eight fourth and fifth grade students eligible for remedial services had taken a CAI reading course and had CTBS vocabulary and reading comprehension scores available. Pre- and posttest mean reading scores for these students and a comparison group of 26 students not in the program are presented in Table 2.7. Both participants and nonparticipants improved in reading achievement from pretest to posttest; participants, however, made greater gains than nonparticipants. Participants gained, on the average,

16 NCE points in vocabulary and 10 NCE points in reading comprehension, as compared with gains of 4 points each for nonparticipants.

Table 2.7

Pre- and Posttest Mean Reading Scores (NCE)
Grades 4 and 5 (Remedial)

Subtest	CAI[a]		Non-CAI[b]	
	Pretest	Posttest	Pretest	Posttest
Vocabulary	22.97	38.87	24.28	28.19
Reading Comprehension	26.46	36.34	25.16	29.65

[a] $\underline{n}$=38

[b] $\underline{n}$=26

In neither skill area was the pretest significantly correlated with the posttest; therefore no adjustment of posttest means was necessary and regular analyses of variance were performed. Table 2.8 shows the results of the analysis of variance of the effects of program participation on reading achievement. There was a significant positive effect of the CAI program on participants' vocabulary achievement over that of nonparticipants. After the program, participants scored over 10 NCE points higher in vocabulary than nonparticipants. Therefore the CAI program had a beneficial effect on vocabulary achievement for grade 4 and 5 remedial students.

The results for reading comprehension show that the program had a borderline significant effect (p=.055) in favor of participants, who had a posttest mean over 6 points higher than nonparticipants. Further analysis,

Table 2.8

Analysis of Variance of Effects of the CAI Program on Reading Achievement, Grades 4 and 5 (Remedial)

Subtest	Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Vocabulary	Program Participation	1759.557	1	1759.557	5.419**
	Residual	20132.309	62	324.715	
Reading Comprehension	Program Participation	690.563	1	690.563	3.838*
	Residual	11154.363	62	179.909	

n=64
*p=.055
**p<.05

however, showed that much of this increase was due to one student who had a posttest mean of 86 in reading comprehension which pulled up the average for the group. Therefore, the CAI program seemed to benefit just a few students rather than having an overall effect for all grade 4 and 5 remedial students in reading comprehension.

2.5 Project Evaluation - Grade 6

2.5.1 Findings (Nonremedial Students)

Thirty-two nonremedial sixth grade students had taken a CAI reading course and had both pre- and posttest CTBS scores available. Pre- and posttest mean reading scores for participants and a comparison group of 43 nonparticipants are presented in Table 2.9. In vocabulary, participants maintained, on the average, approximately the same level of achievement from pretest to posttest, while the comparison group declined by 4 NCE points. In reading comprehension, CAI students gained, on the average, 2.5 points while the comparison group declined in achievement.

Table 2.9

Pre- and Posttest Mean Reading Scores (NCE), Grade 6 (Nonremedial)

Subtest	CAI[a] Pretest	CAI[a] Posttest Unadjusted	CAI[a] Posttest Adjusted	Non-CAI[b] Pretest	Non-CAI[b] Posttest Unadjusted	Non-CAI[b] Posttest Adjusted
Vocabulary	53.91	53.50	51.66	47.00	43.00	44.37
Reading Comprehension	46.59	49.09	48.59	45.14	43.49	43.86

[a] $\underline{n}=32$
[b] $\underline{n}=43$

The analysis of covariance of the effects of the CAI program on reading achievement is presented in Table 2.10. The results show significant beneficial effects of the program for both vocabulary and reading comprehension. Thus the program met its objective of improving vocabulary and reading comprehension achievement over that of nonparticipants for grade 6 nonremedial students.

Table 2.10

Analysis of Covariance of Effects of the CAI Program on Reading Achievement, Grade 6 (Nonremedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Vocabulary Pretest	4976.875	1	4976.875	46.720***
Program Participation	931.906	1	931.906	8.748**
Residual	7669.840	72	106.526	
Reading Comprehension Pretest	3529.648	1	3529.648	38.939***
Program Participation	407.645	1	407.645	4.497*
Residual	6526.551	72	90.647	

$\underline{n}=75$
*$\underline{p} < .05$
**$\underline{p} < .005$
***$\underline{p} < .001$

Four nonremedial students in grade 6 had taken Language Arts 3-6 and had both pre- and posttest language scores available. Their mean pre- and posttest scores in language mechanics and language expression are presented in Table 2.11. These students' achievement in language mechanics (capitalization and punctuation) declined, while their achievement in language expression improved. Because of the small sample, no statistical analyses of these means in comparison with nonparticipants could be performed.

Table 2.11

Pre- and Posttest Mean Language Scores (NCE), Grade 6 (Nonremedial)

Subtest	Pretest	Posttest
Language Mechanics	34.75	32.50
Language Expression	38.75	40.50

n=4

2.5.2 Findings (Remedial Students)

Twenty-one sixth grade students eligible for remedial services had taken a CAI reading course and had complete pre- and posttest CTBS scores available. For this group, it was found that time in the program was an important factor in gains in achievement. Consequently, participants were divided into two groups: those designated as "half year CAI" had accrued less than 15 hours of computer time in reading, roughly corresponding to one half year of program participation; those designated as "full year CAI" had accrued more than 15 hours of computer time in reading. Pre- and posttest mean reading scores for these students and a comparison group of 18 nonparticipants are presented in Table 2.12. In vocabulary, length of time in the CAI program was directly related to achievement: Students in the full year group gained an average of almost 15 NCE points, as compared with almost 6 points for students in the half year group and less than one

Table 2.12

Pre- and Posttest Mean Reading Scores (NCE), Grade 6 (Remedial)

Subtest	Full Year CAI[a] Pretest	Full Year CAI[a] Posttest	Half Year CAI[b] Pretest	Half Year CAI[b] Posttest	No CAI[c] Pretest	No CAI[c] Posttest
Vocabulary	16.09	30.82	23.67	29.33	26.94	27.33
Reading Comprehension	27.18	25.27	19.67	24.50	26.61	31.44

[a] $n=11$
[b] $n=12$
[c] $n=18$

point for nonparticipants. In reading comprehension, there was no systematic relationship between time on task and achievement: Full year students declined an average of two NCE points and half year students gained approximately the same amount as nonparticipants.

For this group, it was found that the pretest correlated with students' time on task (that is, amount of computer time received by students varied systematically with their initial reading level), violating the assumption underlying the analysis of covariance and rendering it an inappropriate method of analysis for this group. Consequently it was necessary to analyze program effects by means of a multiple regression analysis. The results of the multiple regression of the effects of the CAI program on reading achievement are presented in Table 2.13. It was found that the comparison of all CAI participants to nonparticipants showed no significant effects of the program on either vocabulary or reading comprehension achievement. However, the comparison of full year CAI students to nonparticipants showed a significant beneficial effect of the CAI program on students' vocabulary achievement. (Although a significant difference was found in reading comprehension achievement, it was opposite to the prediction and favored nonparticipants over participants.) Therefore there

is evidence that the CAI program improves vocabulary achievement for remedial sixth grade students, if they remain in the program for the full year.

Table 2.13

Multiple Regression of Effects of the CAI Program on Reading Achievement, Grade 6 (Remedial, Full Year CAI Only)

Source of Variation	Percent of Variance	Regression Weight	t
Vocabulary Pretest	.049	.490 (.447)	2.706*
Program Participation	.116	-8.808(-.409)	1.903*
Reading Comprehension Pretest	.012	1.40 (.122)	.663
Program Participation	.102	6.251(.319)	1.729*

Note. Numbers in parentheses are standardized regression coefficients.

n=29
*p <.05

Nine grade 6 remedial students had taken a language arts course (Language Arts 3-6) and had complete CTBS scores available. Pre- and posttest mean language arts scores for these students are presented in Table 2.14. On the average, students made large gains in both language mechanics and language expression (16 and 13 NCE points, respectively). Because of the small sample size, no statistical tests of significance in comparison with nonparticipants could be performed.

Table 2.14

Pre- and Posttest Mean Language Scores (NCE), Grade 6 (Remedial)

Subtest	Pretest	Posttest
Language Mechanics	22.44	38.89
Language Expression	14.89	28.00

n=9

2.6 Project Evaluation - Grades 7 and 8

2.6.1. Findings (Nonremedial Students)

Thirty-five nonremedial students in grades 7 and 8 had taken a CAI reading course and had both pre- and posttest CTBS reading scores available. Pre- and posttest mean reading scores in vocabulary and reading comprehension for these students and a comparison group of 36 nonparticipating students are presented in Table 2.15. It can be seen that CAI participants maintained the same level of achievement in vocabulary and reading comprehension from pre- to posttest, while nonparticipants declined slightly in both areas.

Table 2.15

Pre- and Posttest Mean Reading Scores (NCE), Grades 7 and 8 (Nonremedial)

Subtest	CAI[a]			Non-CAI[b]		
	Pretest	Posttest		Pretest	Posttest	
		Unadjusted	Adjusted		Unadjusted	Adjusted
Vocabulary	41.14	41.51	42.27	46.36	44.25	43.51
Reading Comprehension	44.89	44.37	46.85	52.31	48.19	45.78

[a] $n=35$

[b] $n=36$

The results of the analysis of covariance of the effects of the CAI program on reading achievement are presented in Table 2.16. No significant effects of the program were found for either vocabulary or reading comprehension. Thus there is no evidence that the program improves reading achievement for grade 7 and 8 nonremedial students.

Table 2.16

Analysis of Covariance of Effects of the CAI Program on Reading Achievement, Grades 7 and 8 (Nonremedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Vocabulary Pretest	1069.858	1	1069.858	10.310*
Program Participation	25.926	1	25.926	.250
Residual	7056.438	68	103.771	
Reading Comprehension Pretest	4065.328	1	4065.328	42.691**
Program Participation	18.370	1	18.370	.193
Residual	6475.418	68	6475.418	

n=71
*$p < .005$
**$p < .001$

2.6.2 Findings (Remedial Students)

Twenty seventh and eighth grade students eligible for remedial services had taken a CAI reading course and had both pre- and posttest CTBS scores available. At this level it was found that time on task was a relevant factor in achievement. Thus participating students were divided into two groups: those with less than 15 hours of computer time in reading (corresponding to within one half year of program participation) and those with 15 hours or more of computer time (corresponding to up to one full year of program participation). Pre- and posttest mean reading scores in vocabulary and reading comprehension for the groups equivalent to full year CAI participation, half year CAI participation, and no CAI participation are presented in Table 2.17. In vocabulary, the greatest gains were made by the students in the half year group, with an increase of almost 12 NCE points from pre- to posttest. Full year students declined slightly in vocabulary achievement, while nonparticipants increased by a small amount. In reading comprehension, the full year group gained 4 NCE points, the half year group gained 2 points, and the comparison group declined by 1 point.

Table 2.17

Pre- and Posttest Mean Reading Scores (NCE), Grades 7 and 8 (Remedial)

	Full Year CAI[a]			Half Year CAI[b]			No CAI[c]		
Subtest	Pretest	Posttest Unadj.	Adj.	Pretest	Posttest Unadj.	Adj.	Pretest	Posttest Unadj.	Adj.
Vocabulary	28.50	26.33	24.83	24.71	36.50	36.86	25.09	27.64	27.81
Reading Comprehension	28.00	32.33	33.61	31.57	33.93	32.50	28.96	27.96	28.51

[a] $\underline{n}=6$
[b] $\underline{n}=14$
[c] $\underline{n}=22$

The results of the analysis of covariance of the effects of the CAI program on reading achievement are presented in Table 2.18. A significant effect of the program was found for vocabulary achievement, favoring the half year group; no significant effect was found for reading comprehension. Thus the program had a positive impact on vocabulary achievement for grade 7 and 8 remedial students who had been on the computer for a relatively short time. The reasons for this finding are unclear; perhaps vocabulary

Table 2.18

Analysis of Covariance of Effects of the CAI Program on Reading Achievement, Grades 7 and 8 (Remedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Vocabulary Pretest	654.059	1	654.059	5.769*
Program Participation	911.462	2	455.731	4.019*
Residual	4308.574	38	113.384	
Reading Comprehension Pretest	1812.490	1	1812.490	19.794**
Program Participation	200.186	2	100.093	1.093
Residual	3479.598	38	91.568	

$\underline{n}=42$
*$\underline{p} < .05$
**$\underline{p} < .001$

is a rote skill which can be improved relatively quickly yet may result in boredom and lack of interest in the material if students are drilled for an extended period of time. Thus there may be a "novelty effect," whereby students make greater gains in the early stages of the program which may level off later on. The results also suggest that instructional time may not have been utilized to maximum efficiency because more time on task did not lead to higher achievement. The absence of a significant effect of the program on participants' reading comprehension achievement indicates that the improvements in the mean of the two CAI groups were due to the gains of a few individual students rather than an overall beneficial effect for all participants. Thus for grade 7 and 8 remedial students, the CAI program was effective in improving vocabulary achievement only, with time on task an important related factor.

2.7 Project Evaluation - Grade 9

2.7.1 Findings (Remedial Students)

Only one site conducted a CAI program in reading for monolingual high school students. At this site, all the students receiving CAI in reading were ninth grade compensatory education students. Fourteen students had taken a CAI reading course (Reading 3-6, Reading for Comprehension, or Adult Reading Skills) and had CTBS pre- and posttest scores available. Pre- and posttest mean reading scores in vocabulary and reading comprehension for these students and a comparison group of 14 nonparticipants are presented in Table 2.19. Participants' vocabulary achievement rose by 4 NCE points from pretest to posttest, while their reading comprehension achievement declined by almost 6 points. The comparison group declined as well.

Table 2.19

Pre- and Posttest Mean Reading Scores (NCE), Grade 9 (Remedial)

Subtest	CAI[a] Pretest	CAI[a] Posttest Unadjusted	CAI[a] Posttest Adjusted	Non-CAI[b] Pretest	Non-CAI[b] Posttest Unadjusted	Non-CAI[b] Posttest Adjusted
Vocabulary	18.21	22.79	23.04	28.43	23.14	22.88
Reading Comprehension	23.86	17.93	17.94	27.36	18.50	18.48

[a] $\underline{n}$=14
[b] $\underline{n}$=14

The results of the analysis of covariance of the effects of the CAI program on reading achievement are presented in Table 2.20. No significant effects of the program were found for either vocabulary or reading comprehension. Again, the gain in vocabulary achievement was due to one or two individuals rather than to an overall beneficial effect for all participants. Thus there is no evidence that the CAI program improves reading achievement for grade 9 remedial students.

Table 2.20

Analysis of Covariance of Effects of the CAI Program on Reading Achievement, Grade 9 (Remedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Vocabulary Pretest	11.718	1	11.718	.726
Program Participation	.139	1	.139	.001
Residual	2335.104	25	93.404	
Reading Comprehension Pretest	.513	1	.513	.005
Program Participation	1.967	1	1.967	.019
Residual	2642.232	25	105.689	

$\underline{n}$=28

A language arts course, Fundamentals of English, was also given to ninth grade remedial students. Fourteen students had taken the course and had posttest language arts scores available. Since only one of these students had pretest scores available, no adjustment was made for pretest scores differences and a regular analysis of variance was performed.

Table 2.21 presents CTBS language expressions scores for the CAI group and a comparison group of 16 students. The CAI students had a posttest mean of 30.07, clearly higher than the posttest mean of the comparison group, 19.19. The pretest mean for the comparison group was 33.31. While we do not know the pretest level of the CAI students, the comparison group pretest mean shows some comparability of the two groups, as well as a substantial decline for students not in the program.

Table 2.21

Pre- and Posttest Mean Language Expression Scores (NCE)
Grade 9 (Remedial)

CAI[a]		Non-CAI[b]	
Pretest	Posttest	Pretest	Posttest
-	30.07	33.31	19.19

[a] $n=14$

[b] $n=16$

Table 2.22 presents the results of the analysis of variance of the effects of the CAI program on language expression achievement. There was a significant beneficial effect of the program on achievement as compared with that of the comparison group. Therefore there is evidence that the CAI program has a positive effect on language arts achievement for ninth grade compensatory education students.

Table 2.22

Analysis of Variance of Effect of the CAI Program on Language Expression Achievement, Grade 9 (Remedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Program Participation	884.500	1	884.500	8.722*
Residual	2839.363	28	101.406	

n=30
*$p < .01$

2.8 CAI Management Characteristics and Achievement

2.8.1 Overview

While computer-assisted instruction in general may have various beneficial effects, the degree of its effectiveness may depend upon how it is administered. The schools participating in the regular CAI program conduct the CAI in widely divergent ways; it is possible that certain aspects of program management at different sites may enhance the program's impact on achievement.

Two characteristics of program management were chosen in order to study their effects on achievement. They are described below.

1. Instructional strategy. At some sites the CAI was administered in a classroom setting coordinated with formal instruction related to the CAI lessons, while at other sites it was administered in a pullout setting apart from regular instruction, with extended practice in the form of homework exercises. We wished to determine which was the more effective strategy: CAI administered in the context of a formal lesson, organized in advance and coordinated with the computer work, or CAI administered in the context of extended solitary practice without organized and coordinated instruction.

2. Affective encouragement. At many sites students were actively rewarded for good performance with prizes, certificates, or formal recognition. We wished to determine whether such reinforcement would affect achievement by encouraging students to value accomplishment and to maintain interest and perseverance in the face of difficulties with the material.

2.8.2 Evaluation Design

The analysis was done for elementary students only; since only one high school had a regular program in reading, there was no variation in program characteristics at that level which could be used as a basis for comparison. Additionally, since coordination of instruction was linked to Chapter I services at two sites, only students qualifying for Chapter I services were included.

At the elementary level (grades 4-8) three subgroups were identified with respect to their exposure to the management variables:

1. Students receiving coordinated instruction;

2. Students receiving extended practice as homework, without coordinated instruction;

3. Students receiving extended practice and reinforcement for good performance, without coordinated instruction.

The analysis chosen was a one-way analysis of covariance: After controlling for initial differences in achievement, the groups were compared to see whether there were any differences in post-program achievement attributable to the management variables. In order to determine which instructional strategy was more effective in improving achievement, group 1 was compared with group 2; in order to determine whether reinforcement for good performance was effective in improving achievement, group 3 was compared with group 2.

2.9 Project Evaluation - CAI Management Characteristics and Reading Achievement (Grades 4-8)

2.9.1 Findings (Remedial Students)

The three groups of students studied received the CAI in the context of either formal, coordinated instruction, extended solitary practice, or affective encouragement for good performance. Pre- and posttest means for these three groups in vocabulary and reading comprehension are presented in Table 2.23. All three groups made gains in both vocabulary and reading comprehension. The greatest gains were made by the students receiving affective encouragement; these students gained an average of 16.35 NCE points in vocabulary and 6.5 points in reading comprehension. In vocabulary, the group receiving solitary practice did somewhat better than the group receiving coordinated instruction, while in reading comprehension, the reverse was true.

Table 2.23

Pre- and Posttest Mean Reading Scores (NCE), CAI Management Groups (Grades 4-8 Remedial)

Subtest	Coor. Instruction[a]			Solitary Practice[b]			Attec. Encouragement[c]		
	Pretest	Posttest		Pretest	Posttest		Pretest	Posttest	
		Unadj.	Adj.		Unadj.	Adj.		Unadj.	Adj.
Vocabulary	23.53	26.00	25.86	20.22	27.78	28.30	23.70	40.05	39.87
Reading Comprehension	26.95	29.68	29.49	19.17	22.44	25.75	29.63	36.13	34.73

[a] $\underline{n}=19$
[b] $\underline{n}=18$
[c] $\underline{n}=40$

The results of the analysis of covariance of the effects of instructional strategy on reading achievement are presented in Table 2.24. Significant effects of instructional management were found for both vocabu-

lary and reading comprehension. For vocabulary, affective encouragement was the most effective strategy, followed by solitary practice and lastly by coordinated instruction. For reading comprehension, affective encouragement was the most effective strategy, followed by coordinated instruction and lastly by solitary practice.

Table 2.24

Analysis of Covariance of Effects of CAI Management Characteristics on Reading Achievement (Grades 4-8 Remedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Vocabulary Pretest	428.107	1	428.107	2.429
Management	3196.475	2	1598.237	9.067**
Residual	12867.059	73	176.261	
Reading Comprehension Pretest	2687.536	1	2687.536	22.578**
Management	906.153	2	453.076	3.806*
Residual	8689.445	73	119.033	

$n=77$
$*p < .05$
$**p < .001$

The results of this analysis raised some interesting points about the complexity of factors underlying reading achievement and suggest ways of enhancing the effectiveness of the CAI program for different types of reading skills. It was expected that coordinated instruction would enhance reading achievement more than would extended solitary practice. This was found to be the case for reading comprehension but not for vocabulary. Perhaps vocabulary, involving rote skills rather than conceptual ones, is more amenable to drill and practice than is reading comprehension; in this instance, formal instruction may not contribute substantially to achievement, since extended practice may be needed by the student more than formal

transmission of information. Reading comprehension, on the other hand, involves more conceptual understanding than does vocabulary; in this case formal instruction may be an indispensable addition to extended practice, as drill and practice alone cannot impart such understanding. Therefore the results of this analysis suggest that for rote skills extended drill and practice may be the most useful technique for raising achievement, whereas for abstract conceptual skills, formal instruction is essential; no matter how great the advances in instructional technology, for some skills the teacher cannot be replaced.

Another important issue raised by these results is the finding that no instructional strategy produced achievement gains as great as those produced by affective encouragement of the learner. It seems that no method of instruction concentrated on the acquisition of information is as effective as attention paid to the emotional and motivational state of the student. Again, the instructor's role in enhancing student achievement is vital - but acknowledgement of students' accomplishments and enthusiastic encouragement of future progress are more effective than merely imparting specific knowledge. These results demonstrative the strong psychological element in student achievement - and the value of teachers and aides who respond to it. Therefore a vital component of a successful CAI program would be a concerted effort toward providing students with a sense of pride in their accomplishments; the confidence and interest that result are at least as important as the instruction itself.

2.10 Conclusions and Recommendations

Based on the analyses of reading and language arts achievement for students receiving computer-assisted instruction, it can be concluded that the CAI program was useful in varying degrees for grade 2 through 9 students. The analyses showed the following results:

1. There were no significant beneficial effects for nonremedial students in grades 2 and 3; there were, however, improvements in both vocabulary and reading comprehension for the four remedial students in the program at these grade levels.

2. There was no evidence of a beneficial effect of the program for grades 4 and 5 nonremedial students. For remedial students at this level, there was a significant beneficial effect on vocabulary achievement, and a borderline significant effect on reading comprehension achievement, the latter indicating a beneficial effect for some but not all students in the program in reading comprehension.

3. For grade 6 nonremedial students, there were beneficial effects for both vocabulary and reading comprehension. There was also improvement in language expression achievement for a group of four nonremedial students. For grade 6 remedial students, the program was effective in raising vocabulary achievement over that of nonparticipants if students remained in the program for the full school year; no effect of the program was found for reading comprehension achievement. Large gains were noted in both language mechanics and language expression for nine grade 6 remedial students taking the Language Arts course.

4. There was no evidence of a beneficial effect on reading achievement for nonremedial students in grade 7 and 8. For remedial students, there was a beneficial effect on vocabulary achievement, favoring students who had been in the program for up to one half of the school year.

5. There was no evidence of a beneficial effect on grade 9 compensatory education students' reading achievement; there was, however, a beneficial effect on their language arts achievement.

6. Comparison of three different methods of administering the CAI to remedial elementary students (CAI in the context of formal, coordinated instruction; CAI in the context of extended solitary practice; and CAI in the context of affective encouragement for good performance) showed that for both vocabulary and reading comprehension, affective encouragement produced the highest level of achievement. For reading comprehension only, coordinated instruction produced a higher level of achievement than did solitary practice. Thus the effectiveness of the CAI in reading may be enhanced by specific teacher behaviors which clarify conceptual material and increase students' motivation to achieve.

Therefore there is evidence that computer-assisted instruction improves the achievement of several subgroups of students. A statistically significant result is deemed educationally significant if the improvement in participants' mean achievement over that of nonparticipants is greater than one-third of a standard deviation. By this standard, all the statistically significant findings above are educationally significant as well.

In order to more clearly define the appropriate target population and to improve the effectiveness of computer-assisted instruction in reading, the following recommendations are made:

1. If the goal of computer-assisted instruction is to improve standardized test achievement, then it appears from these results that the regular CAI program is a more useful tool for remedial than for nonremedial students. Gains in achievement were found at almost every grade level for remedial students but only at grade 6 for nonremedial students. A program based on drill and practice of basic reading skills is probably most needed by students having difficulties in that area rather than by students with average achievement. Students with average and above-average reading

skills may benefit more (as for as standardized test scores are concerned) from a program on a somewhat higher skill level (see Chapter 4).

2. Students in grades 2 and 3 are probably too young to derive maximum benefits from computer work. The exceptions would be remedial students in these grades, who may benefit from work in needed basic skills.

3. It appears that the CAI instructor can play a vital role in enhancing the effectiveness of the program. Sincere and explicit acknowledgement of student gains and enthusiastic encouragement of future achievement may do much to motivate students and help them develop pride in their accomplishments, leading to improvement in achievement. Formal instruction where reading content is strongly conceptual in nature is also valuable in enhancing achievement beyond that accomplished by drill and practice alone.

CHAPTER 3

THE REGULAR CAI PROGRAM IN MATHEMATICS

3.1 Project Narrative

3.1.1 Introduction and Objectives

The Computer-assisted Instruction program provided supplementary individualized instruction in mathematics to students in grades 2 through 12 in eleven selected Newark public schools. The program was designed to provide students with intensive drill and practice in math computation and concepts; in some cases, it has been used to facilitate the provision of Chapter I and State Compensatory Education services as well. Students participating in the CAI program in mathematics are expected to demonstrate significant educational progress in mathematical skills.

3.1.2 Selection of Students

The criteria for selection of students for computer-assisted instruction in mathematics varied from one site to another. The most frequent criterion for selection was eligibility for Chapter I or State Compensatory Education services: Two elementary schools used the CAI as an adjunct to their Chapter I instruction and three high schools used it as part of their compensatory math education program. In one high school, convenience of scheduling, in particular the timing of the student's math period, seemed to be the primary criterion for selection. As with the regular CAI program in reading two sites selected students with a wide range of achievement levels, and two selected students with primarily above-average achievement.

The number of students selected varied with the number of terminals installed at each site, which ranged from a low of 4 to a high of 16 at those sites offering mathematics instruction. Approximately 740 students received computer-assisted instruction in mathematics during the 1983-84 school year.

3.1.3 Staff

The staff administering the CAI in mathematics was, for the most part, the same as those administering the CAI curricula in reading. At six sites the program was administered by a teacher aide who supervised the students as they worked individually at the terminals, without providing formal instruction in addition to the CAI. At two sites the CAI was administered by Chapter I teachers who integrated the computer work with regular classroom instruction. At three of the four high schools, the CAI program was offered to regular program students in math only. At one of these sites, the CAI was administered by a teacher with the help of an aide on a pull-out basis without any supplementary instruction. At the two remaining sites, the CAI was in the exclusive domain of the math department and was offered as a supplementary activity within the context of compensatory math education classes taught by regular math teachers.

As with the regular CAI program in reading, the role of the CAI staff members at each site varied depending on the structure of the program at the particular school. At most schools offering the CAI on a pull-out basis, the teacher aide was responsible for supervising the sessions but not for providing formal instruction. The degree of informal attention, however, varied from one site to another. In the schools providing the CAI as an adjunct to Chapter I or compensatory education services, there was a considerable amount of formal instruction structured around the CAI.

Individual supervisors also varied in the extent to which they provided homework supplementing the lessons and concrete rewards for successful performance on the computer; the former occurred more frequently when formal instruction was provided, and the latter when the CAI was administered on a pull-out basis, perhaps because the usual instructional feedback was not present. Thus, in math as well as in reading, the nature of the CAI administration varied greatly depending on how the program was conceived and staffed at each site.

3.1.4 Educational Setting

The setting in which the CAI was administered varied with the structure of the program at each individual site. In those schools in which the CAI was administered on a pull-out basis, students worked in a separate computer room used only for the CAI program. In schools using the CAI as part of Chapter I or compensatory education instruction, the CAI took place in a regular classroom; in these cases, students received a half-period of regular instruction and then took turns doing seatwork related to the lesson and working at the computer terminals.

3.1.5 Computer Hardware

The CAI program in mathematics employs the same computer and terminals as in the reading program. Each site is supplied with one printer and several terminals provided by the Computer Curriculum Corporation of Palo Alto, California. The terminals are modems connected to the mini-computer installed at the Board of Education and are available in groups of four; the number of terminals at each side varies from 4 to 16 for the program in mathematics. Reports regularly obtained from the computer are course reports, providing students' current scores, and monthly gain reports.

3.1.6 Activities and Materials

At most sites, students worked for approximately 20 minutes per day at the terminals, spending half of the time on reading and half on math. If only math was offered at the site, they spent ten minutes per day on math. (At one site students did not work on the computer every day, so their total time was extended to 40 minutes per session.) The computer courses consist of intensive drill and practice in math computation and concepts, adjusted to the student's individual level of proficiency. The courses (with the exception of the Adult Skills courses, used in the high schools) contain one hour and forty minutes of initial placement, in which the computer adjusts the course material upward and downward to match the student's level of ability. Students' scores are available from the computer-generated reports.

Four mathematics courses were used in the regular CAI program. They are briefly described below; more detailed descriptions may be found in Appendix C.

Mathematics 1-6 (MA). The most basic math course, it consists of number concepts, basic computational skills in vertical and horizontal formats, equations, fractions and decimals, negative numbers, and measurement, presented for grade levels 1 thru 6.

Mathematics 7 and 8 (MM). MM continues where MA left off, emphasizing fractions, decimals, signed numbers, equations, inequalities, measurement, and number theory, aimed at grade levels 7 and 8.

Problem Solving 3-6 (PS). PS is designed to provide practice in solving word problems rather than computation. Problems deal with money; ages; measure; number systems; time, rate, and distance; and geometry. It

is aimed toward grades 3 to 6 and also toward older students requiring remediation in problem solving skills.

Adult Arithmetic Skills (AAS). AAS covers topics equivalent to those presented in MA; however, it is aimed toward adults requiring remediation rather than toward children. It contains no initial placement and can be worked through more rapidly than MA. It is used in the high schools only.

3.2 Project Evaluation - Overview

3.2.1 Evaluation Design

The objective of the regular CAI program in mathematics is to help participating students improve their mathematics achievement beyond the level that would be expected through the regular classroom instruction alone. The evaluation model used to determine whether this objective had been met was, as for the regular program in reading, the analysis of covariance. (The details of this procedure have been explained in section 2.2 and are elaborated in Appendix A.) If, after adjusting for prior achievement, program participants show a higher level of achievement at the end of the year than nonparticipants, then the program may be said to have been effective in meeting the stated objective.

Achievement preceding and following the CAI program was measured by the Comprehensive Tests of Basic Skills (CTBS), forms U and V, 1981, administered throughout the Newark School District in May 1983 and May 1984. All CTBS scores were normal curve equivalents (NCE). A comparison group of students not in the program was randomly selected from Newark's Student Information System so as to be equivalent in Total Math achievement to the

3.3 Project Evaluation - Grades 2 and 3

3.3.1 Findings (Nonremedial Students)

Sixty nonremedial second and third grade students had taken a CAI mathematics course (Mathematics 1-6) and had both pre- and posttest CTBS scores available. Pretest and posttest mean mathematics scores in computation and concepts and applications (in NCEs) for program participants and a comparison group are presented in Table 3.2 (The adjusted posttest means represent the means the two groups would have been expected to obtain had they been exactly equal to each other on the pretest; this controls for any initial differences between the groups.) In math computation, both participants and nonparticipants increased by approximately the same amount (2 NCE points); in concepts and applications, both groups declined (participants by 6.42 NCE, nonparticipants by 7.31 NCE).

Table 3.2

Pre- and Posttest Mean Mathematics Scores (NCE), Grades 2 and 3 (Nonremedial)

Subtest	CAI[a]			Non-CAI[b]		
	Pretest	Posttest		Pretest	Posttest	
		Unadjusted	Adjusted		Unadjusted	Adjusted
Computation	62.70	64.20	64.02	58.81	61.07	61.33
Concepts and Applications	59.50	53.08	52.91	58.24	50.93	51.19

[a] $n=60$

[b] $n=42$

group of program participants; when feasible, nonparticipants were selected from the same schools as participants.

As with the regular program in reading, analyses were done separately by grade level, course, and eligibility for remedial services. The grade level groups studied were grades 2 and 3, grades 4 and 5, grade 6, grades 7 and 8, and grades 9-12. Math courses studied were Math 1-6, Math 7 and 8, Problem Solving 3-6, and Adult Arithmetic Skills. Only students were included who had progressed beyond the initial placement period (the first hour and forty minutes) of the courses studied. CTBS levels and Total Math remedial cutoff scores are presented in Table 3.1.

Table 3.1

CTBS Level, Form, and Remedial Cutoff Scores for Each Grade in the Regular CAI Program in Mathematics

Grade Level	Test Level and Form	Remedial Cutoff Score (NCE)
1	A,U	42
2	D,U	28
3	E,U	44
4	E,V	44
5	F,U	44
6	G,V	42
7	G,U	42
8	H,V	42
9	H,U	42
10	J,U	34
11	J,V	29
12	J,U	-

The results of the analysis of covariance of the effects of the CAI program on grade 2 and 3 mathematics achievement are presented in Table 3.3. No significant effects of the program were found on achievement in either computation or concepts and applications. Therefore there is no evidence that the CAI program benefits grade 2 and 3 nonremedial students' mathematics achievement.

Table 3.3

Analysis of Covariance of Effects of the CAI Program on Mathematics Achievement, Grades 2 and 3 (Nonremedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Computation Pretest	450.764	1	450.764	1.244
Program Participation	176.615	1	176.615	.487
Residual	35886.664	99	362.491	
Concepts and Applications Pretest	2804.454	1	2804.454	15.359*
Program Participation	73.222	1	73.222	.401
Residual	18076.254	99	182.588	

n=102
*$p < .001$

3.3.2 Findings (Remedial Students)

Only five grade 2 and 3 students eligible for remedial services had taken a CAI mathematics course (Mathematics 1-6) and had both pretest and posttest CTBS scores available. Table 3.4 shows their pretest and posttest means in computation and concepts and applications. These students made notable gains in both areas: They gained an average of 27 NCE points in computation and 6 NCE points in concepts and applications. (The greater gain in computation than in concepts is not surprising since Mathematics 1-6 stresses computation much more than concepts and applications.) Because the group was very small, no statistical tests of significance in comparison to nonparticipants could be performed.

Table 3.4

Pre- and Posttest Mean Mathematics Scores (NCE),
Grades 2 and 3 (Remedial)

Subtest	Pretest	Posttest
Computation	23.80	50.80
Concepts and Applications	39.40	45.40

n=5

3.4 Project Evaluation - Grade 4 and 5

3.4.1 Findings (Nonremedial Students)

Twenty-nine fourth and fifth grade nonremedial students had taken a CAI mathematics course (Mathematics 1-6) and had both pre- and posttest CTBS scores available. Pre- and posttest mean mathematics scores in computation and concepts and applications for participants and a comparison group are presented in Table 3.5. In computation, both groups declined, participants by 14 NCE points and nonparticipants by 8. In concepts, participants declined by 4 NCEs and nonparticipants by 2.

Table 3.5

Pre- and Posttest Mean Mathematics Scores (NCE),
Grades 4 and 5 (Nonremedial)

Subtest	CAI[a]			Non-CAI[b]		
	Pretest	Posttest		Pretest	Posttest	
		Unadjusted	Adjusted		Unadjusted	Adjusted
Computation	77.14	62.86	62.26	73.03	65.00	65.52
Concepts and Applications	52.55	48.76	48.27	50.12	48.15	48.57

[a] n=60

[b] n=42

The results of the analysis of covariance of the effects of the CAI program on grade 4 and 5 mathematics achievement are presented in Table 3.6. No significant effects of the program were found in either computation or concepts and applications. Therefore there is no evidence that the CAI program has a beneficial effect on grade 4 and 5 nonremedial students' mathematics achievement.

Table 3.6

Analysis of Covariance of Effects of the CAI Program on Mathematics Achievement, Grades 4 and 5 (Nonremedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Computation Pretest	1305.109	1	1305.109	2.701
Program Participation	163.808	1	163.808	.339
Residual	28991.973	60	483.199	
Concepts and Applications Pretest	1884.530	1	1884.530	8.177*
Program participation	1.339	1	1.339	.006
Residual	13827.473	60	230.458	

$n=63$

*$p < .01$

Twelve nonremedial fourth and fifth grade students had taken the CAI course in Problem Solving. Since the content of this course differs substantially from that of Mathematics 1-6, it was analyzed separately. Pre- and posttest means in math concepts and applications for participants and nonparticipants are presented in Table 3.7. Participants' achievement remained at approximately the same level, while nonparticipants declined slightly.

Table 3.7

Pre- and Posttest Mean Math Concepts and Applications Scores (NCE), Grades 4 and 5 Problem Solving (Nonremedial)

CAI[a]			Non-CAI[b]		
Pretest	Posttest		Pretest	Posttest	
	Unadjusted	Adjusted		Unadjusted	Adjusted
48.08	48.67	49.21	50.12	48.15	47.95

[a] n=12

[b] n=34

The results of the analysis of covariance of the effect of the CAI program on grade 4 and 5 math concepts and applications achievement are presented in Table 3.8. No significant effect on achievement was found. Therefore there is no evidence that CAI Problem Solving benefits grade 4 and 5 nonremedial students' math concepts and applications achievement.

Table 3.8

Analysis of Covariance of Effects of the CAI Program on Math Concepts Applications Achievement, Grades 4 and 5 Problem Solving (Nonremedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Concepts and Applications Pretest	1000.206	1	1000.206	4.313*
Program Participation	14.064	1	14.064	.06
Residual	9972.992	43	231.930	

n=46

*$p < .05$

3.4.2 Findings (Remedial Students)

Thirty-five fourth and fifth grade students eligible for remedial services had taken a CAI mathematics course (Mathematics 1-6) and had both pre- and posttest CTBS scores available. Pre- and posttest mean mathematics scores in computation and concepts and applications for these students and a comparison group of 34 nonparticipants are presented in Table 3.9. On the average, CAI students gained approximately nine NCE points in computation as compared with five points for nonparticipants; CAI students gained approximately eight points in concepts and applications as compared with 5.5 for nonparticipants.

Table 3.9

Pre- and Posttest Mean Mathematics Scores (NCE), Grades 4 and 5 (Remedial)

Subtest	CAI[a]			Non-CAI[b]		
	Pretest	Posttest		Pretest	Posttest	
		Unadjusted	Adjusted		Unadjusted	Adjusted
Computation	38.40	47.57	46.27	33.52	37.68	39.02
Concepts and Applications	27.97	35.74	35.53	27.15	32.62	32.83

[a] $n=35$

[b] $n=34$

The results of the analysis of covariance of the effects of the CAI program on mathematics achievement are presented in Table 3.10. There was a significant effect due to the program for computation achievement but not for concepts and applications achievement, showing an overall beneficial effect for all participants only in computation, as compared with the gains of nonparticipants. Therefore there is evidence that the Mathematics 1-6 course benefits grade 4 and 5 remedial students' computation achievement, but not their concepts and applications achievement.

Twenty-nine grade 4 and 5 remedial students had taken Problem Solving 3-6 and had complete test score data available. Their mean math concepts and applications scores in comparison with those of nonparticipants are presented in Table 3.11. Participants gained an average of nine NCE points while nonparticipants gained only five.

Table 3.10

Analysis of Covariance of Effects of the CAI Program on Grades 4 and 5 Mathematics Achievement (Remedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Computation Pretest	3313.575	1	3313.575	15.468**
Program Participation	864.037	1	864.037	4.033*
Residual	14138.918	66	214.226	
Concepts and Applications Pretest	1812.560	1	1812.560	14.023**
Program Participation	125.617	1	125.617	.972
Residual	8530.898	66	129.256	

$n=69$
*$p < .05$
**$p < .001$

Table 3.11

Pre- and Posttest Mean Math Concepts and Applications Scores (NCE), Grades 4 and 5 Problem Solving (Remedial)

CAI[a]			Non-CAI[b]		
Pretest	Posttest		Pretest	Posttest	
	Unadjusted	Adjusted		Unadjusted	Adjusted
31.04	40.48	39.70	27.34	32.69	33.33

[a] $n=29$

[b] $n=35$

The results of the analysis of covariance of the effect of the CAI program on math concepts and applications achievement are presented in Table 3.12. There was a significant beneficial effect of the program on participants' math concepts achievement. Therefore there is evidence that Problem Solving 3-6 improves math concepts and applications achievement for grade 4 and 5 remedial students.

Table 3.12

Analysis of Covariance of Effects of the CAI Program on Math Concepts and Applications Achievement, Grade 4 and 5 Problem Solving (Remedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Concepts and Applications Pretest	1362.586	1	1362.586	9.082**
Program Participation	624.063	1	624.063	4.159*
Residual	9152.199	61	150.036	

n=64
*$p < .05$
**$p < .005$

3.5 Project Evaluation - Grade 6

3.5.1 Findings (Nonremedial Students)

Twenty-three nonremedial sixth grade students had taken a CAI mathematics course (Mathematics 1-6) and had complete test score data available. Pre- and posttest mean computation and concepts scores for participants and a comparison group of 22 nonparticipants are presented in Table 3.13. In computation, participants gained over 4 NCE points while nonparticipants gained less than 2 points. In concepts, participants declined by more than 2 points while nonparticipants remained at approximately the same level.

The results of the analysis of covariance of the effects of the CAI program on mathematics achievement are presented in Table 3.14 There was a significant effect of the program for computation achievement but not for concepts and applications achievement. Therefore there is evidence that the CAI program benefits grade 6 nonremedial students in math computation achievement.

Table 3.13

Pre- and Posttest mean Mathematics Scores (NCE), Grade 6 (Nonremedial)

	CAI[a]			Non-CAI[b]		
Subtest	Pretest	Posttest Unadjusted	Adjusted	Pretest	Posttest Unadjusted	Adjusted
Computation	78.92	83.26	82.85	70.71	71.95	72.38
Concepts and Applications	64.88	62.04	57.91	51.19	51.45	55.78

[a] $n=23$

[b] $n=22$

Table 3.14

Analysis of Covariance of Effects of the CAI Program on Mathematics Achievement, Grade 6 (Nonremedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Computation Pretest	468.910	1	468.910	1.704
Program Participation	1191.462	1	1191.462	4.329*
Residual	11560.379	42	275.247	
Concepts and Applications Pretest	5702.191	1	5702.191	32.346**
Program Participation	43.005	1	43.005	.244
Residual	7403.957	42	176.285	

$n=45$

*$p < .05$

**$p < .001$

Twelve students had taken Problem Solving 3-6 and had both pre- and posttest math concepts scores available. Their means and the means of the comparison group are presented in Table 3.15. Participants declined by an average of 8 NCE in math concepts while nonparticipants remained at approximately the same level.

Table 3.15

Pre- and Posttest Mean Math Concepts and Applications Scores (NCE), Grade 6 Problem Solving (Nonremedial)

CAI[a]			Non-CAI[a]		
Pretest	Posttest		Pretest	Posttest	
	Unadjusted	Adjusted		Unadjusted	Adjusted
72.83	64.75	58.05	51.19	51.45	55.11

[a] $n=12$

[b] $n=22$

The results of the analysis of covariance of the effect of the CAI program on math concepts achievement are presented in Table 3.16. No significant effect of the program was found. Therefore there is no evidence that CAI in problem solving benefited grade 6 nonremedial students' concepts and applications achievement.

Table 3.16

Analysis of Covariance of Effect of the CAI Program on Math Concepts and Applications Achievement, Grade 6 Problem Solving (Nonremedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Concepts and Applications Pretest	3345.132	1	3345.132	15.056*
Program Participants	47.524	1	47.524	.214
Residual	6887.574	31	222.180	

$n=34$

*$p < .001$

3.52 Findings (Remedial Students)

Sixty sixth grade students eligible for remedial services had taken the CAI course Mathematics 1-6 and had complete test score data available. Pre- and posttest mean mathematics scores for these students and a comparison group are presented in Table 3.17. Though both participants and nonparticipants made gains in both skill areas, gains made by participants exceeded those made by nonparticipants. In computation, participants gained almost 20 NCE points, as compared with an average gain of 13 NCE points for nonparticipants; in concepts, participants' gains averaged 15.5 points as opposed to almost 10 for nonparticipants.

Table 3.17

Pre and Posttest Mean Mathematics Scores (NCE), Grade 6 (Remedial)

	CAI[a]			Non-CAI[b]		
	Pretest	Posttest		Pretest	Posttest	
Subtest		Unadjusted	Adjusted		Unadjusted	Adjusted
Computation	38.02	57.80	57.61	37.57	50.64	50.90
Concepts and Applications	26.10	41.63	41.38	25.00	34.76	35.12

[a] $\underline{n}$=60

[b] $\underline{n}$=42

The results of the analysis of covariance of the effects of the CAI program on mathematics achievement are presented in Table 3.18. Significant effects were obtained for both computation and concepts achievement. Therefore there is evidence that the CAI program benefits grade 6 remedial students in both math computation and concepts and applications achievement.

Fifty-two students had taken Problem Solving 3-6 and had test scores available. Their mean math concepts scores and those of nonparticipants are presented in Table 3.19. Participants gained an average of almost 17 NCE points. as opposed to almost 10 for the comparison group.

Table 3.18

Analysis of Covariance of Effects of the CAI Program on Mathematics Achievement, Grade 6 (Remedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Computation Pretest	5220.121	1	5220.121	21.444***
Program Participation	1110.670	1	1110.670	4.563*
Residual	24099.832	99	243.433	
Concepts and Applications Pretest	1599.298	1	1599.298	13.494***
Program Participation	962.970	1	962.970	8.125**
Residual	11733.668	99	118.522	

$n=102$
*$p < .05$
**$p \leq .005$
***$p < .001$

Table 3.19

Pre- and Posttest Mean Math Concepts and Applications Scores (NCE), Grade 6 Problem Solving (Remedial)

CAI[a]			Non-CAI[b]		
Pretest	Posttest		Pretest	Posttest	
	Unadjusted	Adjusted		Unadjusted	Adjusted
26.94	43.69	43.11	25.00	34.76	35.48

[a] $n=52$

[b] $n=42$

The results of the analysis of covariance of the effects of the CAI program on math concepts achievement are presented in Table 3.20. A significant effect was obtained for participants as compared with nonparticipants. Therefore there is evidence that CAI in problem solving benefits grade 6 remedial students' math concepts and applications achievement. It should be noted that most of these students were in the group who had shown improvement in math concepts after taking mathematics 1-6; therefore it is difficult to determine which course was more responsible for the gain. However, the content of the two courses, plus test score evidence, suggest that the greater credit should be given to Problem Solving for the improvement in math concepts and applications: Mathematics 1-6 contains very little content in concepts and applications; students in Problem Solving showed a larger NCE gain in concepts and applications after the students only in Math 1-6 had been excluded; and results in grades 4 and 5 show improvement in math concepts only for those taking Problem Solving in addition to Math 1-6. Therefore it seems likely that Mathematics 1-6 is most appropriate for improving achievement in computation, while Problem Solving is preferable for concepts and applications achievement.

Table 3.20

Analysis of Covariance of Effect of the CAI Program on Math Concepts and Applications Achievement, Grade 6 Problem Solving (Remedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Concepts and Applications Pretest	2378.883	1	2378.883	16.245**
Program Participation	1326.704	1	1326.704	9.060*
Residual	13325.934	91	146.439	

n=94
*$p < .005$
**$p < .001$

3.6 Program Evaluation - Grades 7 and 8

3.6.1 Findings (Nonremedial Students)

Twenty-nine nonremedial students in grades 7 and 8 had taken a CAI mathematics course (Mathematics 1-6 or Mathematics 7 & 8) and had complete CTBS scores available. Pre- and posttest mean mathematics scores for participants and a comparison group of 31 students are presented in Table 3.21. In computation both participants and nonparticipants declined by similar amounts (around 4 NCE). In concepts, participants remained at the same level while nonparticipants gained 2 NCE.

Table 3.21

Pre- and Posttest Mean Mathematics Scores (NCE), Grades 7 and 8 (Nonremedial)

Subtest	CAI[a]			Non-CAI[b]		
	Pretest	Posttest		Pretest	Posttest	
		Unadjusted	Adjusted		Unadjusted	Adjusted
Computation	62.14	57.56	58.93	68.69	65.42	64.33
Concepts and Applications	49.28	49.00	50.21	52.92	55.10	53.97

[a] n=29

[b] n=31

The results of the analysis of covariance of the effects of the CAI program on mathematics achievement are presented in Table 3.22. No significant effects were found in either computation or concepts and applications. Therefore there is no evidence that the CAI program was effective in improving the mathematics achievement of grade 7 and 8 nonremedial students.

Table 3.22

Analysis of Covariance of Effects of the CAI Program on Mathematics Achievement, Grades 7 and 8 (Nonremedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Computation Pretest	2142.864	1	2142.864	8.196*
Program Participation	417.002	1	417.002	1.595
Residual	14902.223	57	14902.223	
Concepts and Applications Pretest	3758.029	1	3758.029	27.354**
Program Participation	206.647	1	206.647	1.504
Residual	7830.918	57	137.385	

[a] $n=60$
*$p < .01$
**$p < .001$

3.6.2 Findings (Remedial Students)

Twenty-nine grade 7 and 8 students eligible for remedial services had taken a CAI mathematics course (Math 1-6 or Math 7 & 8) and had complete test score data available. Pre- and posttest mean mathematics scores for these students and a comparison group are presented in Table 3.23. In computation, participants gained an average of 6 NCE points as compared with less than 2 points for nonparticipants; in concepts, participants gained 5 points while nonparticipants gained 4.

Table 3.23

Pre- and Posttest Mean Mathematics Scores (NCE), Grades 7 and 8 (Remedial)

Subtest	CAI[a] Pretest	CAI[a] Posttest Unadjusted	CAI[a] Posttest Adjusted	Non-CAI[b] Pretest	Non-CAI[b] Posttest Unadjusted	Non-CAI[b] Posttest Adjusted
Computation	39.83	45.90	45.16	37.88	39.00	39.85
Concepts and Applications	28.10	33.24	32.43	24.76	29.84	30.79

[a] $n=29$
[b] $n=25$

The results of the analysis of covariance of the effects of the CAI program on mathematics achievement are presented in Table 3.24. Despite the larger NCE gain obtained by participants in computation, no significant effects were found in either skill area. The gain in computation made by participants was found to be the result of large gains made by a few students which pulled up the group mean, rather than an overall beneficial effect for all participants. Therefore there is no evidence that the CAI program is effective in raising the mathematics achievement of all participating remedial students in grades 7 and 8.

Table 3.24

Analysis of Covariance of Effects of the CAI Program on Mathematics Achievement, Grades 7 and 8 (Remedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Computation Pretest	4268.777	1	4268.777	26.587*
Program Participation	376.072	1	376.072	2.342
Residual	8188.344	51	160.556	
Concepts and Applications Pretest	1205.766	1	1205.766	25.308*
Program Participation	34.402	1	34.402	.722
Residual	2429.827	51	47.644	

n=54
*$p < .001$

3.7 Project Evaluation - Grades 9-12

3.7.1 Findings (Nonremedial Students)

Thirty nonremedial students in grades 9-12 had taken a CAI mathematics course (Mathematics 1-6, Mathematics 7 & 8, or Adult Arithmetic Skills) and had complete CTBS scores available. Pre- and posttest mean mathematics scores for these students and a comparison group are presented

in Table 3.25. Both participants and nonparticipants declined by similar amounts in both computation and concepts and applications.

Table 3.25

Pre- and Posttest Mean Mathematics Scores (NCE), Grades 9-12 (Nonremedial)

Subtest	CAI[a] Pretest	CAI[a] Posttest Unadjusted	CAI[a] Posttest Adjusted	Non-CAI[b] Pretest	Non-CAI[b] Posttest Unadjusted	Non-CAI[b] Posttest Adjusted
Computation	54.70	53.00	54.17	57.35	55.75	55.06
Concepts and Applications	42.57	39.37	40.28	44.49	40.69	40.15

[a] $n=30$

[b] $n=51$

The results of the analysis of covariance of the effects of the CAI program on mathematics achievement are presented in Table 3.26. No signficant effects were found for either computation or concepts and applications. Therefore there is no evidence that the CAI program improves mathematics achievement for grade 9-12 nonremedial students.

Table 3.26

Analysis of Covariance of Effects of the CAI Program on Mathematics Achievement, Grades 9-12 (Nonremedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Computation Pretest	7981.145	1	7981.145	37.095*
Program Participation	14.642	1	14.642	.068
Residual	16782.125	78	215.155	
Concepts and Applications Pretest	7089.031	1	7089.031	76.762*
Program Participation	.340	1	.340	.004
Residual	7203.352	78	92.351	

$n=81$

*$p < .001$

Four grade 9-12 nonremedial students had taken Problem Solving 3-6. Their mean pretest and posttest scores in math concepts and applications are presented in Table 3.27. These students gained slightly more than 2 NCE points in math concepts. Because of the small sample size, no statistical tests of significance in comparison with nonparticipants could be performed.

Table 3.27

Pre- and Posttest Mean Math concepts and Applications Scores (NCE), Grades 9-12 Problem Solving (Nonremedial)

Pretest	Posttest
46.25	48.75

n=4

3.7.2 Findings (Remedial Students)

One hundred and eighty-five compensatory education students in grades 9-12 had taken a CAI mathematics course (Mathematics 1-6, Mathematics 7 & 8, or Adult Arithmetic Skills) and had complete test scores available. Pre- and posttest mean mathematics scores for participants and nonparticipants are presented in Table 3.28. In computation, participants gained over 4 NCE points while nonparticipants lost one point. In concepts, participants gained two points while nonparticipants remained at approximately the same level.

The results of the analysis of covariance of the effects of the CAI program on mathematics achievement are presented in Table 3.29. A significant effect of the program was found on students' computation achievement; no significant effect was found on students' concepts and applications achievement. Thus there is evidence that the CAI program improves compensatory education high school students' computation achievement, but not their concepts and applications achievement.

Table 3.28

Pre- and Posttest Mean Mathematics Scores (NCE), Grades 9-12 (Remedial)

Subtest	CAI[a] Pretest	CAI[a] Posttest Unadjusted	CAI[a] Posttest Adjusted	Non-CAI[b] Pretest	Non-CAI[b] Posttest Unadjusted	Non-CAI[b] Posttest Adjusted
Computation	29.90	34.14	35.05	33.46	32.10	31.28
Concepts and Applications	21.14	23.95	24.78	25.22	24.92	24.20

[a] n=185

[b] n=210

Table 3.29

Analysis of Covariance of Effects of the CAI Program on Mathematics Achievement, Grades 9-12 (Remedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Computation Pretest	12635.922	1	12635.922	90.134**
Program Participation	1367.848	1	1367.848	9.757*
Residual	54954.793	392	140.191	
Concepts and Applications Pretest	4436.063	1	4436.063	41.065**
Program Participation	31.372	1	31.372	.290
Residual	42237.930	392	108.025	

n=395
*p <.005
**p <.001

Forty-eight students had taken Problem Solving 3-6 and had complete CTBS scores available. Pre- and posttest mean math concepts and applications scores for participants and nonparticipants are given in Table 3.30. Participants had an average gain of almost 3 NCE points, as compared with less than one for nonparticipants.

Table 3.30

Pre- and Posttest Mean Math Concepts and Applications Scores (NCE), Grades 9-12 Problem Solving (Remedial)

CAI[a]			Non-CAI[b]		
Pretest	Posttest Unadjusted	Adjusted	Pretest	Posttest Unadjusted	Adjusted
21.67	24.50	25.44	25.15	25.65	24.79

[a] $\underline{n}=48$

[b] $\underline{n}=52$

The results of the analysis of covariance of the effect of the CAI program on math concepts achievement are presented in Table 3.31. No significant overall effect on achievement was found. Therefore there is no evidence that Problem Solving improves the math concepts and applications achievement of grade 9-12 compensatory education students.

Table 3.31

Analysis of Covariance of Effect of the CAI Program on Math Concepts and Applications Achievement, Grades 9-12 Problem Solving (Remedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Concepts and Applications Pretest	1779.209	1	1779.209	19.088*
Program Participation	10.232	1	10.232	.11
Residual	9041.414	97	93.210	

$\underline{n}=100$

*$\underline{p} < .001$

3.8 Project Evaluation - Special Education

3.8.1 Findings

Eight elementary special education students received computer-assisted instruction during the 1983-84 school year. These students studied Mathematics 1-6. Of these eight students, both pre- and posttest scores were available for only four; additionally, three out of these four students did not have pretest scores in mathematics computation, as they had been given Level A of the CTBS which contains no math computation subtest. Mathematics concepts and applications scores were available for the four students.

Pre- and posttest scores for the four students were examined to determine whether there was improvement in their scale scores in mathematics after participation in the CAI program. (Since special education students were tested at their functional level, norm-reference scores could not be used). The one student for whom pre- and posttest mathematics computation scores were available showed no change in this area. Of the four students, three showed improvement in mathematics concepts and applications. The average scale score in mathematics concepts and applications before participation was 430 for these four students; the average scale score after participation was 483.25.

3.9 CAI Management Characteristics and Achievement

3.9.1 Overview

In mathematics as well as in reading, the manner in which computer-assisted instruction is administered may influence its effects on

achievement. Since the schools participating in the regular CAI program vary widely in their mode of conducting the program, we wished to determine whether certain management characteristics would enhance program effectiveness. The management characteristics studied were instructional strategy (i.e., whether the CAI is integrated into formal, coordinated instruction or whether it is presented in the context of extended solitary practice) and affective encouragement (reinforcement in the form of rewards for achievement in the CAI courses). Each of these has been described more fully in section 2.8.1. Study of these characteristics of CAI administration can provide useful information as to how to program may be used to maximize student gains in achievement.

3.9.2 Teacher Comments About CAI Management

In the process of studying the nature and effects of CAI management, some interesting issues emerged regarding the management of the CAI program in mathematics in the high schools. At one high school, the CAI is administered in a pullout format by a teacher aide, while at two high schools, the CAI is administered in a classroom setting by math teachers as part of compensatory education math classes.

At the site in which the CAI functioned on a pullout basis, the teacher aide expressed some disappointment that the teachers were not more involved with the actual administration of the program. Yet at the two sites in which the CAI was used in the regular classroom, a number of teachers expressed dismay at the excessiveness of the demands placed upon them in conducting many activities with large classes and little time: They must teach a lesson, supervise boardwork and seatwork, and answer questions from students working at the terminals, often simultaneously. One teacher compared this situation to "a three-ring circus," saying that

her attention must be divided up by too many activities at once, diminishing her effectiveness. A number of teachers remarked that they felt they could do more to exploit the full potential of CAI, but they just did not have any more time or attention left to do so.

Several teachers at both sites suggested that valuable help could be provided by a teacher aide who would be available to answer students' questions as they worked on the computer, freeing teachers for more direct instructional tasks. While one teacher felt that the ideal situation would be a separate computer lab, others felt that it would be preferable to have an aide working within the regular classroom; in this way continuity of instruction would be maintained and teachers would also be able to reach more students.

From these comments, it appears that judging the effectiveness of different formats of administration of CAI is more difficult than it would seem; yet format may be an valuable aspect of the program's effectiveness. These are important issues to consider in addition to the computer work itself.

3.9.3 Evaluation Design

The analysis of the effects of CAI management characteristics on achievement was done in two parts: for elementary students and for secondary students. In both cases students were included only if they qualified for Chapter I and State Compensatory Education services, since this was a criterion for selection at a number of schools.

At the elementary level (grades 4-8) three subgroups were identified:

1. Students receiving coordinated instruction;

2. Students receiving extended practice as homework, without coordinated instruction;

3. Students receiving extended practice and reinforcement for good performance, without coordinated instruction.

Results were analyzed by a one-way analysis of covariance: After controlling for initial differences in achievement, the groups were compared to see whether there were any differences in post-program achievement attributable to the management variables. In order to determine which instructional strategy was more effective in improving achievement, group 1 was compared with group 2; in order to determine whether reinforcement for good performance had a beneficial effect on achievement, group 3 was compared with group 2.

At the secondary level (grades 9-12) two groups were identified with respect to management of the program:

1. Students receiving coordinated instruction, reinforcement, and extended practice in the form of homework;

2. Students receiving neither coordinated instruction nor reinforcement nor extended practice as homework, but only the CAI on a pull-out basis.

An analysis of covariance was done in order to compare these two groups: After adjustment for initial differences in achievement, were there any differences in post-program achievement attributable to exposure or nonexposure to the management variables?

3.10 Project Evaluation - CAI Management Characteristics and Mathematics Achievement

3.10.1 Findings (Grades 4-8 Remedial Students)

The three groups of elementary students studied received the CAI in the context of either formal, coordinated instruction, extended solitary practice, or affective encouragement for good performance. Pre- and posttest means for these three groups in mathematics computation and concepts and applications are presented in Table 3.32. All three groups made gains in both computation and concepts. The greatest gains were made by the students receiving coordinated instruction; these students gained on the average, 16.86 NCE points in computation and 15.23 points in concepts. Intermediate gains were made by those receiving affective encouragement (10.04 in computation and 7 in concepts), and the smallest (though by no means small) by those receiving solitary practice (9.56 in computation and 5.56 in concepts).

Table 3.32

Pre- and Posttest Mean Mathematics Scores (NCE), CAI Management Groups (Grades 4-8 Remedial)

Subtest	Coor. Instruction[a]			Solitary Practice[b]			Affec. Encourag.[c]		
	Pretest	Posttest		Pretest	Posttest		Pretest	Posttest	
	Unadj.	Unadj.	Adj.	Unadj.	Unadj.	Adj.	Unadj.	Unadj.	Adj.
Computation	38.71	55.57	55.61	37.13	46.69	47.39	39.47	49.51	49.23
Concepts and Applications	26.62	41.85	42.08	25.44	31.00	31.73	28.40	35.40	34.87

[a] $n=61$

[b] $n=16$

[c] $n=47$

The results of the analysis of covariance of effects of instructional strategy on mathematics achievement are presented in Table 3.33. Significant effects of instructional management were found for both computation and concepts and applications. In both cases, coordinated instruction was the most effective strategy, followed by affective encouragement and lastly by extended solitary practice.

Table 3.33

Analysis of Covariance of Effects of CAI Management Characteristics on Mathematics Achievement (Grades 4-8 Remedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Computation Pretest	3875.196	1	3875.196	15.779**
Management	1494.919	2	747.459	3.043*
Residual	29471.633	120	245.597	
Concepts and Application Pretest	1505.140	1	1505.140	14.291**
Management	2101.642	2	1050.821	9.978**
Residual	12638.063	120	105.317	

$n=124$
*$p < .05$
**$p < .001$

The implication of these findings is that, as for reading achievement, the context in which the CAI is administered may have a substantial impact on its effectiveness; however, the optimum setting for mathematics achievement is different from that for reading achievement. For mathematics, formal, coordinated instruction is vital both for strongly conceptual and (seemingly) rote skills. Apparently in both areas of mathematics formal explanation of concepts and procedures is essential to students'

understanding. Drill-and-practice CAI can augment mathematics instruction but cannot replace it, for the computer can only tell a student when an answer is incorrect, but cannot explain why it is incorrect. Motivational factors may also play an important role: As with reading, teacher behaviors which acknowledge and encourage student achievement can spur students on to greater achievement gains even without instruction coordinated with CAI lessons. Thus, a CAI program for remedial elementary students centered on drill and practice alone can be effective in producing gains in mathematics; if teacher encouragement is added, gains can be augmented; but maximum benefits are most likely to occur if the CAI is integrated with formal mathematics instruction.

3.10.2 Findings (Grades 9-12 Remedial Students)

The two groups of secondary students studied with respect to management of the CAI were those receiving coordinated instruction, extended practice, and affective encouragement for good performance, and those receiving the CAI alone with neither coordinated instruction, extended practice, nor affective encouragement. Pre- and posttest means for these two groups in math computation and concepts and applications are presented in Table 3.34. The group receiving formal instruction coordinated with the CAI lessons gained in achievement in both computation and concepts and applications, by 7 and 3 NCE points, respectively. The group receiving solitary practice alone gained 2 NCE points in concepts and applications but did not gain in computation.

Table 3.34

Pre- and Posttest Mean Mathematics Scores (NCE), CAI Management Groups (Grades 9-12 Remedial)

Subtest	Coordinated Instruction[a] Pretest	Posttest Unadjusted	Posttest Adjusted	Solitary Practice[b] Pretest	Posttest Unadjusted	Posttest Adjusted
Computation	27.40	34.28	35.91	33.63	33.33	31.11
Concepts and Applications	21.79	24.25	24.17	21.18	23.59	23.70

[a] $\underline{n}=67$
[b] $\underline{n}=49$

The results of the analysis of covariance of the effects of instructional strategy on mathematics achievement are presented in Table 3.35. A significant effect of instructional management was found for math computation achievement favoring the group receiving coordinated instruction. No significant effect was found for concepts and applications achievement. Therefore there is evidence that formal classroom instruction in mathematics structured around CAI lessons combined with reinforcement for good performance enhances secondary students' computation achievement beyond that produced by the CAI alone.

Table 3.35

Analysis of Covariance of Effects of CAI Management Characteristics on Mathematics Achievement (Grades 9-12 Remedial)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Computation Pretest	5322.129	1	5322.129	38.391***
Management	612.723	1	612.723	4.420*
Residual	15665.270	113	138.631	
Concepts and Applications Pretest	1033.771	1	1033.771	9.716**
Management	6.356	1	6.356	.060
Residual	12022.641	113	106.395	

$\underline{n}=116$
*$\underline{p}<.05$
**$\underline{p}<.005$
***$\underline{p}<.001$

These results suggest that for secondary students as well as for elementary students, the role of the instructor is crucial in enhancing achievement gains. Mathematics computation, while it may seem to emphasize rote skills, apparently requires a certain degree of conceptual understanding as well, which may be more effectively imparted by a coordinated system of instruction than by drill and practice alone. Once again, CAI in mathematics effective in producing achievement gains; but for maximum benefits, it is most helpful to have CAI integrated with formal mathematics instruction.

3.11 Conclusions and Recommendations

Based on the analyses of mathematics achievement for students receiving computer-assisted instruction, it can be concluded that the CAI program was useful in varying degrees for grade 2-12 students. the analyses showed the following results:

1. There were no significant beneficial effects for nonremedial students in grades 2 and 3; there were, however, improvements in both math computation and concepts and applications for the five remedial students at these grade levels.

2. There was no evidence of an effect of the program for grades 4 and 5 nonremedial students. For remedial students at these grade levels, there was a beneficial effect of the Mathematics 1-6 course on math computation achievement and a beneficial effect of the Problem Solving 3-6 course on math concepts and applications achievement.

3. For grade 6 nonremedial students, there was a beneficial effect of Mathematics 1-6 on math computation achievement; there were no significant effects of either of the courses on math concepts and applications

achievement. For grade 6 remedial students, there were significant improvements in both computation and concepts and applications, the former attributable to Mathematics 1-6 and the latter to Problem Solving 3-6.

4. For grades 7 and 8, there were no significant effects on mathematics achievement for either nonremedial or remedial students.

5. For nonremedial secondary students, no significant program effects were found although four students made gains in math concepts and applications after studying Problem Solving 3-6. For compensatory education students at this level, a positive impact was found for math computation but no for concepts and applications, attributed to the Mathematics 1-6 , Mathematics 7 & 8, and Adult Arithmetic Skills courses.

6. Three out of a group of four special education students improved in math concepts achievement after taking Mathematics 1-6.

7. Comparison of three different methods of administering the CAI to remedial elementary students (CAI in the context of formal, coordinated instruction; CAI in the context of extended solitary practice; and CAI in the context of affective encouragement for good performance) showed that for both computation and concepts and applications, coordinated instruction produced the highest level of achievement, followed by affective encouragement and lastly by solitary practice. Thus the effectiveness of the CAI in mathematics may be enhanced by specific teacher behaviors which clarify concepts and procedures and increase students' motivation to achieve.

8. Comparison of two different methods of administering the CAI to remedial secondary students (CAI in the context of formal, coordinated instruction, extended practice, and encouragement for good performance; CAI in the context of solitary practice alone) showed that CAI in the context of formal, coordinated instruction was more effective in producing gains in

math computation achievement than was drill-and-practice CAI alone. Thus the effectiveness of CAI in mathematics is enhanced by teacher behaviors which clarify and integrate conceptual material for secondary as well as for elementary students.

Therefore there is evidence that computer-assisted instruction improves the achievement of several subgroups of students. A statistically significant result is deemed educationally significant if the improvement in participants' mean achievement over that of nonparticipants is greater than one third of a standard deviation. By this standard, all the statistically significant findings above are educationally significant as well.

In order to more clearly defined the appropriate target population and to improve the effectiveness of computer-assisted instruction in mathematics, the following recommendations are made:

1. As with the regular CAI program in reading, the regular program in mathematics appears to be more useful for remedial than for nonremedial students, if the objective is to improve standardized test achievement. Gains in achievement were found at most grade levels for remedial students, and only at grade 6 for nonremedial students. A program based on drill and practice of basic mathematical skills is probably most appropriate for students having difficulties with basic skills rather than for students with average achievement.

2. It is important to identify the specific mathematical skills one wishes to improve when selecting a CAI mathematics course. Mathematics 1-6, Mathematics 7 & 8, and Adult Arithmetic Skills are most appropriate for improving achievement in math computation; Problem Solving 3-6 is most appropriate for improving achievement in math concepts and applications.

3. As with CAI in reading, students in grades 2 and 3 are probably too young to derive maximum benefits from computer work. The exceptions would be remedial students in these grades, who may benefit from work in needed basic skills.

4. It appears that the CAI instructor can play a vital role in enhancing the effectiveness of the program in mathematics. Formal instruction coordinated with CAI lessons is indispensable for maximizing student gains in achievement. Affective encouragement of students is also helpful in raising achievement beyond that accomplished by CAI alone.

Chapter 4

THE ENRICHMENT CAI PROGRAM

4.1 Project Narrative

4.1.1 Introduction and Objectives

There are several CCC software programs used by above average students in the Newark school system. The purpose is to provide more challenging activities and thereby enrich the curriculum of these students. The programs are: Critical Reading Skills, Mathematics Enrichment Modules, for grades 7 and 8, Introduction to Algebra, Survival Skills, and Exploring Careers. Students at Lafayette Street School are also learning the BASIC programming language on Data General computer terminals.

Critical Reading Skills (CRS) is the most common enrichment curriculum. Students at Lafayette, Bergen, Cleveland, Avon, Elliott and one student at McKinley were all using CRS. This curriculum requires the ability to apply critical reading skills to subject matter. There are two sections to the program: vocabulary and reading comprehension. In the vocabulary section there are 760 target words, each of which is presented three times in different questions and contexts so that the student gets a feel for the different usages of the word. In the reading comprehension section there are 150 reading passages. After reading a passage, a student is asked questions. For example, the student may be asked to determine motivation of a character, make inferences, determine sequence of events, or state the relationship of one idea to another. In this section there are tutorial messages following wrong answers. These messages are designed to help students understand the question or to explain where they went

wrong in their reading and/or comprehension. The reading comprehension passages are arranged sequentially in order of levels of reading difficulty.

The Mathematics Enrichment Modules, Grades 7 and 8 (EM) curriculum used at Lafayette Street School is a supplementary math program whose contents are generally not included in seventh and eighth grade mathematics courses. These contents include: sets, geometry, statistics, probability, logic, and functions and graphing. Each module contains lessons that build upon one another. The EM curriculum also presents tutorial messages. If a student's answer is incorrect, there will be a computer message giving a hint as to how to work the problem or saying what is wrong with the answer.

Introduction to Algebra (ALG) is a beginning algebra course used by ninth graders at Barringer Prep. It teaches basic algebraic concepts and techniques for solving equations. A text accompanies the course. The student reads a lesson in the text and then answers questions and works exercises related to that lesson at the computer terminal. When a student does an exercise incorrectly, the program tells why the answer is wrong or shows the correct procedure to use.

Survival Skills is a course used at Elliott Street and Lafayette Street Schools which is developed to apply reading and mathematical skills to materials and situations in everyday life. The curriculum consists of independent modules in the areas of health and nutrition, consumer skills, employment, transportation and entertainment, personal finance, and using informational sources. There is a textbook which is to be used with the computer lessons. Like the programs mentioned above, Survival Skills also contains tutorial messages which both reinforce correct answers and provide guidance when answers are incorrect.

BASIC (Beginners All-Purpose Symbolic Instructional Code) programming language is one of several computer languages. COBOL, FORTRAN, and LOGO are others. Students at Lafayette Street school are learning BASIC. It is the language most commonly used with microcomputers and it is an all-purpose language. Learning a computer language allows one to communicate with the computer and tell it what to do. It gives the student some active control over the computer.

4.1.2 Selection of Students/Staff/Activities

The criteria by which students were selected for computer instruction, the staffing, and the programs used for enrichment purposes varied from school to school. Thus, each school will be discussed separately.

4.1.2.1 Lafayette Street School

Thirty-three students identified as being eligible for the Gifted and Talented Program were using several computer programs. These students from grades 6 through 8 had to be reading at least two years above grade level in order to qualify for the program. In addition to Critical Reading Skills (CRS), they used Mathematics Enrichment Modules (EM), Exploring Careers (EX) and a few were using Survival Skills (SS). They were also learning BASIC programming language. They spent 30 minutes each afternoon in the Gifted and Talented Program. Three days were spent using the CRS and EM programs and two were spent using EX, SS and learning BASIC.

There was a certified teacher who worked with the pupils in the Gifted and Talented Program. She speaks English, Spanish and Portuguese and, thus, could communicate in all of the students' native languages. She instituted a reinforcement system whereby student performance was rewarded weekly with gold stars. She monitored student progress on the computer and

also checked classroom progress so that computer activity supplemented classroom activity.

4.1.2.2 Elliott Street School

Eight above-average 6th grade students were selected for CAI instruction. High test scores on the Comprehensive Test of Basic Skills (CTBS) administered in May, 1983, and ease of scheduling were the criteria used for selection. These students utilized several of the same programs used by remedial students, albeit at a higher level - Math, Grades 1-6 (MA), Reading for Comprehension (RC), and Problem Solving (PS). During the latter half of the year, they also used Survival Skills (SS) and two used Critical Reading Skills (CRS). During the course of the year, two of the original eight students transferred out of the school, and each was replaced on the computer by another student shortly thereafter.

A certified reading teacher was responsible for the enrichment program. The eight students were pulled out of the classroom for 40 minutes per day. In the computer room they alternated between computer instruction and teacher instruction, i.e., 4 students were on the computer for 20 minutes while the other 4 were with the teacher. They then switched for the next 20 minutes.

4.1.2.3 Bergen Street and Cleveland Schools

Students were selected for CAI instruction at both Bergen Street and Cleveland Schools from a range of ability groups - as determined by their test scores on the Comprehensive Test of Basic Skills (CTBS) administered in May, 1983. They were then placed in CAI courses appropriate to their skill level. The more able students "topped out of" or successfully completed the Reading for Comprehension (RC) course and were then placed in Critical Reading Skills (CRS). There were a total of 15 students from

Bergen Street and eight students from Cleveland in CRS who are included in the analysis of the enrichment program. These students were also using the Math, Grades 1-6 course, although at a higher level of difficulty than remedial students.

At both schools students were pulled out of the classroom for 20 minutes of CAI instruction each day. Half of the time was spent on math and half on reading.

A teacher aide was responsible for all CAI activity at Bergen. She did not instruct the students, but she did give homework and she reinforced the students' performance weekly with prizes, certificates, charts on the wall, etc.

A teacher aide was also responsible for CAI activity at Cleveland. She was very supportive of students, although she did not instruct them directly. She gave homework regularly. At the end of the year students received Tee shirts and other awards for their CAI participation and performance.

4.1.2.4 Avon Avenue School

Seven high achieving sixth grade students (as determined by CTBS scores) were chosen for participation in the CAI enrichment program at Avon. They were originally placed in the Reading Comprehension and Math, Grades 1-6 courses. Four of these students "topped out" of the Reading Comprehension courses and were then placed in Critical Reading Skills. These four students are included in our analysis here.

Students received 24 minutes of computer instruction daily (half in math and half in reading). A teacher aide is responsible for all CAI instruction. These sixth grade students received homework once a week.

4.1.2.5 Barringer Prep

Introduction to Algebra (ALG) is being used by 16 high achieving ninth grade students, and is being supervised by the classroom teacher. Thus, there is more coordination between computer activity and classroom activity than at any of the above schools.

4.2 Project Evaluation

4.2.1 Evaluation Design

The students who used the Critical Reading Skills (CRS) program were expected to perform better on both Vocabulary and Reading Comprehension CTBS subtests than those without CAI experience. A sample group of students of comparable ability (as determined by 1983 CTBS scores) was drawn from the non-CAI students. Analysis of covariance was then used to test the difference between the mean scores of the control group and the CAI group on the 1984 CTBS subtests, using their 1983 scores as a covariate.

Similarly, those students enrolled in the Mathematics Enrichment Modules, Grades 7 and 8 (EM) were expected to perform better on the CTBS math subtests than students not enrolled. Analysis of covariance was again used to test the difference between CAI users and non-users, using their 1983 CTBS scores as a covariate.

Descriptive information regarding pretest and posttest mathematics subtest scores are presented for students enrolled in the Introduction to Algebra (ALG) Program.

Survival Skills (SS) and Exploring Careers (EX) are programs giving students information is other areas of life than basic skills. Thus, students using these programs were not expected to perform differently on

the basic skills tests and consequently an evaluation was not done for these courses.

4.2.2 Results: Critical Reading Skills (CRS)

There were a total of 53 students included in the analysis. The number is smaller than the number enrolled in the CRS course, because not all students had both pre and posttest CTBS data, and some students had not been using the course long enough to be placed. An hour and forty minutes of "practice" time is necessary before the computer is able to assign students to their appropriate skill levels in the course, and it is at that point that the student can then begin to progress.

Table 4.1 presents the pre and posttest mean scores on the Vocabulary and Reading Comprehension subtests for both the CRS students and the non-CAI group. In the case of the posttest scores both the unadjusted and adjusted means are presented. The unadjusted mean is simply the mean score of the group without taking account of any other factors. The adjusted mean is the mean score of the group after the effects of the pretest score have been accounted for.

In all cases the mean NCE scores were lower on the posttest than on the pretest. The expectation was that students using the CRS course would perform better on reading subtests than those not using it. As can be seen from the results in Table 4.1, this means that the question of performance is not in terms of relative gain but, rather, in terms of relative loss. Scores of those using the CRS course will decline less than those not using it.

The non-CAI student samples were drawn from an above average population in order to ensure that there would not be a systematic difference

between CRS users and nonusers. Although the mean scores of the CRS group are slightly higher on the pretest, the range of scores in all groups is similar. Analysis of covariance, using the pretest as the covariate, was chosen to test the difference between the posttest mean scores of the CRS and non-CAI groups. Whatever effects pretest differences might have on postest differences could, therefore, be controlled for.

Table 4.1

Pre & Posttest Mean NCE Scores of CTBS Reading Subtests: CRS Students and NonCAI Students

	CRS			NON-CAI		
	Pretest	Posttest Unadjusted	Adjusted	Pretest	Posttest Unadjusted	Adjusted
Vocabulary	68.08 (N=53)	64.96	63.59	60.81 (N=42)	50.76	52.49
Reading Comprehension	70.38 (N=53)	69.00	67.12	63.12 (N=50)	59.90	61.89

Tables 4.2 and 4.3 summarize the results of the analysis. The effects of the pretest scores on posttest scores are accounted for initially and, as the F score indicates, the pretest scores do have a significant effect. The primary question is, however, what effect does the CRS course have on posttest scores. As can be seen in Table 4.2, the relationship is significant in the case of vocabulary at the .001 level. Students using the CRS course have a significantly higher mean score on the Vocabulary subtest than do non-CAI students.

The difference between the mean posttest scores on the Reading Comprehension subtest is not significant, however, (see Table 4.3) After the effects of the pretest score have been removed, there is no real difference in performance between CRS users and those not using the

course. The Critical Reading Skills course, thus, seems to have had greater impact on vocabulary skill development than on reading comprehension skill development.

Table 4.2

ANCOVA Summary Table: Vocabulary

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Vocabulary Pretest	7503.844	1	7503.844	57.794*
CRS Program	2775.527	1	2775.527	21.377*
Residual	11945.008	92	129.837	

n=45
*$p < .001$

Table 4.3

ANCOVA Summary Table: Reading Comprehension

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Reading Comprehension Pretest	6819.691	1	6819.691	31.408*
CRS Program	657.672	1	657.672	3.029
Residual	21713.531	100	217.135	

n=103
*$p < .001$

4.2.3 Results: Mathematics Enrichment Modules, Grades 7 & 8 (EM)

Thirty students had sufficient data to be included in the analysis of the effects of the EM program. As was true of CRS students, some EM students did not have both pre and posttest CTBS scores, and some had not been using the course long enough to be placed at their appropriate skill levels.

Table 4.4 indicates the pre- and posttest mean scores on the Math Computation and Math Concepts and Applications subtests for EM users and non-CAI users.

Table 4.4

Pre and Posttest Mean Scores of CTBS Mathematics Subtests: EM Students and NonCAI Students

	EM			NON-CAI		
	Pretest	Posttest Unadjusted	Posttest Adjusted	Pretest	Posttest Unadjusted	Posttest Adjusted
Computation	80.91 (N=30)	85.15	85.15	80.84 (N=37)	72.05	72.05
Concepts and Applications	80.03 (N=30)	79.10	76.91	67.06 (N=32)	61.09	63.16

The mean score of the group using the EM course increased on the Computation subtest, but decreased slightly on the Concepts and Applications subtest. Scores of the non-CAI users declined on both subtests. There was no difference between the unadjusted and adjusted means on the posttest of the computation subtest, and as can be seen in Table 4.4, the pretest means were virtually identical. Differences in pretest scores accounted for virtually none of the difference in posttest scores.

The above point is substantiated in Table 4.5 below. The Computation pretest scores account for none of the variation in posttest scores. The F is not at all significant. However, there is a significant difference between EM users and non-CAI users after the pretest effects are removed. (The F is significant at the .001 level.) Clearly, those using the EM course performed better on the Computation subtest than those not using the course.

The same is true of the Concepts and Applications subtest (see Table 4.6). Here, however, the difference on the pretest scores did affect the posttest score difference. The important message for the analysis, though, is that those students using the Math Enrichment Modules scored significantly better on both mathematics subtests than those not in the CAI program.

Table 4.5

ANCOVA Summary Table: Computation

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Computation Pretest	2.726	1	2.726	0.013
EM Program	2848.006	1	2848.006	13.809*
Residual	13199.820	64	206.247	

n=67
*$p < .001$

Table 4.6

ANCHOVA Summary Table: Concepts & Applications

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Concepts & Applications Pretest	3689.718	1	3689.718	19.253*
EM Program	2229.052	1	2229.052	11.631*
Residual	11306.848	59	191.641	

n=62
*$p < .001$

4.2.4 Results: Introduction to Algebra (ALG)

The number of students having both pre- and posttest CTBS scores is 10. This is too small a number to use analysis of covariance. Therefore, a simple description of the data is presented in Table 4.7. Each student's pre- and posttest NCE scores on the mathematics subtest are shown, together with an indication as to whether there was an increase or decrease in NCE points. The mean scores are also shown.

Table 4.7

Pre and Posttest NCE Scores of
Algebra Students on Mathematics Subtests

Student	Computation			Concepts & Applications		
	Pretest	Posttest	Gain or Loss	Pretest	Posttest	Gain or Loss
1	76	99	+23	69	52	-17
2	65	49	-16	41	26	-15
3	53	88	+35	52	59	+7
4	76	88	+12	40	57	+17
5	44	58	+14	39	47	+8
6	59	58	-1	48	47	-1
7	82	99	+17	99	67	-32
8	62	47	-15	41	28	-13
9	91	88	-3	82	62	-20
10	56	58	+2	52	43	-9
Mean	66.4	73.2	+6.8	56.3	48.8	-7.5

Three students (#3, 4, 5) progressed on both of the subtests, and three students (#2, 6, 9) had lower scores on both posttests than on the pretests. Overall, performance on the Computation subtest improved by an average of 6.8 NCE points. Six of the 10 students had higher scores in 1984 than in 1983. Such was not the case for Concepts and Applications. The average score was 7.5 NCE points lower, and seven of the 10 students were responsible for the decline.

In general, both Computation and Concepts and Applications scores decline from 8th to 9th grade in Newark. This is true at all achievement levels, including the top quartile. The mean NCE for Computation was 8.5 NCE points lower for 9th graders in the top quartile this year as compared to the top quartile of 8th graders last year (55.4 and 63.9 respectively). The mean NCE for Concepts and Applications was 4.6 points lower (46.4 and 51.0). The higher computation scores of the Algebra students are, thus, counter to the trend, and give some credence to the possibility that the Introduction to Algebra Program had an effect.

4.2.5 Conclusions and Recommendations

Students using CAI courses for "enrichment" purposes seem, for the most part, to have profitted, particularly in the areas of reading vocabulary and the mathematics subtests. Students using the Critical Reading Skills course had a significantly higher mean score on the CTBS Vocabulary subtest than students not using the course. Students using the Math Enrichment Modules, grades 7 and 8 course had significantly higher scores on both Math Computation and Math Concepts and Applications subtests than did non-CAI users.

The analysis of covariance used to test the difference between the mean scores of those using computer programs and those not using such

programs tested for statistical significance only. A more stringent test is that for educational significance. If the difference between the adjusted mean scores of the two groups is greater than one third of the standard deviation of the posttest score of the control group, the difference is considered to be educationally significant. By this criterion, all of the above differences which reached statistical significance were also educationally significant.

Students using the Introduction to Algebra course had higher posttest scores in math computation. This is contrary to the general decline in math scores from 8th to 9th grades, suggesting that the course was effective in the computation skill area.

It seems worthwhile, then, to continue the enrichment programs, perhaps allocating more time to the reading comprehension component of the Critical Reading Skills course. If there are components in the algebra program which could enhance performance on the Math Concepts and Applications subtest, then more time should be allocated to those components, also. Otherwise, more class time could be devoted to the objectives of this subtest.

CHAPTER 5

BILINGUAL CAI PROGRAM

5.1 Project Narative

5.1.1 Introduction and Objectives

The bilingual component of the Computer-assisted Instruction (CAI) program grew out of the Bilingual Resource Laboratory. The latter program funded since the 1976-77 school year under the Elementary and Secondary Education (ESEA) Title VII Act, provided individualized instruction to 200 bilingual pupils in grades three through nine. Most of the curricula presently in use throughout the CAI program were first tested at three BRL sites: Lafayette School, William H. Horton School at the elementary level, and Barringer Prep at the secondary level.

For the year 1983-84, the Newark Board of Education picked up the complete funding of the Computer-assisted Instruction program and expanded it to include nonbilingual students not only at the above-mentioned sites, but also at nine new locations. Two of these new locations, McKinley and Elliott Street schools, include a small bilingual component at the 5th and 7th grade levels. Despite this addition in the number of sites, the actual number of bilingual students served through the CAI program went from approximately 200 down to 166.

To the great majority of these 166 participants, with a recognized limitation in their English proficiency (LEP students), the program provides supplemental assistance with communication skills and mathematical skills. The objective in each skill area is to help every student progress to an academic level higher than could be reached through the general educational program alone. Two standardized instruments are used to assess academic progress: for communication skills it is the Language Assessment

Battery (LAB, 1982 edition); for mathematics it is the Spanish version of the Comprehensive Tests of Basic Skills (CTBS/Espanol, 1978 edition).

5.1.2 Selection of Students

The bilingual students who participated in the computer-assisted program have been identified through the following three-stage process:

Stage I: Screening. A Home Language Survey is sent to every student's parents. This helps establish whether he/she comes from a bilingual environment.

Stage II: Proficiency Testing. These students identified as non-native speakers of English are administered the Language Assessment Battery (LAB). This set of tests measure English proficiency in four skill areas: Listening, speaking, reading, and writing. Any pupil whose LAB score is at or below the 19th percentile is deemed to have "Limited English Proficiency" and in need of bilingual/ESL services.

Stage III: Program Assignment. The CAI program is one of several options available to students in need of ESL services. Assignment to the program is commonly based on teacher's recommendations. Although a Teacher Rating Sheet has sometimes been used for that purpose, this part of the selection process is the least systematic. In the following table are presented the ratios, at each grade level, of bilingual CAI participants to the number of LEP students at those particular sites.

5.1.3 Program Structure

There is a CAI lab at each of the schools, and at four of the five sites it is located in a separate classroom giving the program a full pull-out format. In general, at each site there are eight CAI workstations, except at Mckinley School where there is a total of only four CRTs.

Table 5.1

Enrollment of LEP Students Participating in the CAI Program

Grade	School					
	Elliott	McKinley	Lafayette	Horton	Barringer	Total
4	-	2/7	3/15	-		5/22
5	8/59	4/25	8/20	-		20/104
6	-	-	8/18	41/46		49/64
7	-	4/56	10/23	-		14/79
8	-	-	11/23	-		11/28
9	-	-	-	-	82/90	67/90
Total	8/59	10/88	40/101	41/46	67/90	166/387

The participants, as can be seen in the table above, come from six grade levels (four through nine) and are organized into ten different small group or classes at the elementary level, and nine groups at the secondary level. The cohesiveness of these classes varies with the procedure used to pull students into the CAI lab. At four of the sites (McKinley, Barringer, Horton, and Elliott), students are brought to the lab in groups of four or eight, all from the same homeroom and at the same time. At Lafayette, students from different grade levels come to the lab one-by-one, and each one takes his/her turn at the workstation as soon as another student completes his/her assignment. Regardless of the turn-around procedure, each student spends, on the average, 20 minutes a day on the CAI. The better part of each session is spent on reading skills and only a fraction of the time on math. The learning activities are individualized, although

the general curricula are common to all participating pupils. In the elementary school, there are two reading curricula most often in use: Reading Comprehension (RC) and Language Skills (LS). Two other communication skills curricula have been explored by less than 4 percent of the students. The math curricula available on the CCC Program were used by LEP students only at Lafayette School, and scores were obtained just for Math 1-6 (MA) and Problem Solving (PS). At the secondary school level, there is one main reading curriculum: the Adult Reading Skills (ARS); a few students have explored the Reading Comprehension package intended for the elementary level, but did not do so consistently. The focus of the program at the high school level seems to have been on mathematics. This is probably due to the fact that the anchorperson for the program was an algebra teacher. The most often studied courses have been the Adult Arithmetic Skills (AAS), followed by the Math 7 and 8 package (MM). The difficulty level of the course seems to have been appropriate since only 24 students out of the 82 ninth graders who participated in the program were able to "top out", i.e., successfully complete the majority of the learning items in the package.

5.1.4 Staffing

A total of ten people worked on implementing the Computer-assisted Instruction. At McKinley, Lafayette, and Elliott one teacher aide was in charge of the program. At Barringer Prep, one algebra teacher and two teacher aides organized the instructional monitoring. At William H. Horton School, as many as four people were involved in the program: a community aide, two project teachers, and a Chapter I coordinator. One of the strong features of the program is that the majority of the staff members are bilingual (Spanish/English or Portuguese/English), therefore, capable of

providing guidance to the students in their native language, when necessary. The staff thus does not act simply as monitors, but also as learning resources. This direct, if periodic, intervention of the instructor in the interaction between an individual pupil and the computer adds a new dimension to the program: it makes it less of a pure drill and practice and more of a tutorial approach. Another form of intervention by the staff aims at fostering student motivation. On type of motivation used year round by the staff is the 95 percent or 100 percent poster which lists a student's name every time he/she achieves that level of accuracy in a lesson. Another type of motivational approach considered at Barringer Prep and McKinley delays the gratification until the end of the year when a plaque or trophy will be awarded to successful students.

There are of course variations from site to site in the degree of instructional and/or motivational support offered by the staff. The activties that are common to everyone pertain to monitoring and include:

a) Preparing each students' CAI program according to his/her level of academic performance.

b) Maintaining accurate records of student's progress.

c) Meeting with classroom teachers to coordinate the CAI activities with the regular instructional program.

d) Meeting with parents to inform them of student's adjustment and progress through the program.

5.2 Project Evaluation

5.2.1 Program Effectiveness

English proficiency has been selected as the principal criterion of effectiveness since the population under study is bilingual while the entire curriculum is in English. The measuring instrument was the Language Assessment Battery administered before and after a year of participation in

the program. To determine effectiveness, the LAB performance of students who received CAI instruction was compared to that of a group of students, from the same schools and at the same grade level, who did not have the benefits of the program. A regression analysis was conducted relating students' LAB performance in 1984 with a pretest measure of English proficiency and an index of participation in the program.

5.2.2 Program Efficiency

The issue of efficiency is of interest only if the program has been found to be effective. As defined here, efficiency related to two educational points: time-on-task and curriculum strength. First of all, if the program is efficient, one would expect that the more instructional time a student received, the better his/her performance would be; however, if the emphasis is not being put in the right place, length of time or exposure to the program may become irrelevant. Secondly, the strength of the program may rest more in one curriculum area than another. That kind of variation, if present, must be underlined in order to improve instructional management. Each of these two points was analyzed with a regression procedure. For students who participated in the program, the relationship between total time on reading tasks and LAB posttest scores was estimated after controlling for pretest differences. Then whenever possible, the total time investment was analyzed into smaller units corresponding to two main curriculum areas: reading comprehension and language arts; the dependence of English proficiency on each of these units was studied.

5.2.3 Skills Transfer

Skills transfer is to be understood as a positive relation between the CAI gains and academic development. Academic development is measured on

the CTBS-Espanol, so this part of the evaluation is limited to the Spanish-speaking students. The CAI gains represent the score change observed for each student on the CAI curriculum between November and May. Raw scores differences tend to be unreliable; however, these gains happen to be highly correlated (around +.80) with the amount of time spent on the computer. So for the analysis, time-on-task was again used as the main predictive variable. Along with an appropriate measure of pretest achievement, it was related, through a regression procedure to CTBS/E Vocabulary and CTBS/E Reading Comprehension respectively. This approach has the potential for enriching understanding of the program's impact. Indeed, while a correlation on the positive side would suggest transfer of academic skill, a correlation on the negative side would raise the possibility that the CAI investment is at the expense of the regular bilingual education program.

5.3 Evaluation Technique

5.3.1 Evaluation Design

To facilitate the evaluation, program participants at the elementary schools were grouped into three clusters: students in grades four and five were designated as the primary group; students in grade six formed an intermediate group; finally, the seventh and eighth graders were designated as the advanced group. To demonstrate how well the bilingual component of the CAI program worked for each of the above groups, three related questions were addressed:

a) Is the program effective in developing English proficiency?

b) If the program is effective, how efficient is its educational management?

c) Are the skills acquired through the program transferable, i.e., do they tend to strengthen overall reading achievement?

When it came to the mathematics component of the program, data were available to investigate only the first two questions.

5.3.2 Findings - Communication Skills

5.3.2.1 Primary Grades

Program Effectiveness. The data to support the claim of effectiveness of the program in grades four and five were obtained from thirty-one students seventeen of whom received CAI instruction for the entire year. As one can see from Table 5.2, the computer-assisted instruction had a positive and significant impact on students' proficiency in English (b = 6.57). After controlling for possible differences ininitial achievement, 10 percent of the variance in the LAB performance can be attributed to participation in the program. To put it in more practical terms, the students who received CAI instruction achieved an average score of 6.57 points higher than did those who were not part of the program.

Table 5.2

Regresssion of 1984 LAB Scores on CAI Participation

Statistics / Variables	R^2	b	F	N
LAB Pretest	.53	.72	40.04*	
CAI	.10	6.57	7.77*	
Combination	.63		24.27*	31

Program Efficiency. While the main program objective was attained, it is important to establish how well the instructional sequence has been managed. The evidence gathered (see Table 5.3) suggests some deficiencies at this grade level. Indeed, the negative regression coefficient (-.71) indicates that the benefits achieved were not commensurate to the amount of time devoted to CAI tasks; the students with the least amount of time were the ones with the better end-of-year performance on the LAB. To further elucidate this point (and rule out the possibility of a regression effect), the relationship between the LAB pretest and CAI time was also studied. The correlation observed was equal to +.59. So, it is clear that the students initially most proficient in English did spend the most time on the computer, but with the smallest returns. This finding brings into focus the following point: at the primary grade level, some parts of the curriculum may not hold great utility, at least not for students who have already developed a certain degree of proficiency in English. In an attempt to identify these curriculum segments, the LAB posttest scores were regressed on various time factors corresponding to the different components of the curriculum (see Table 5.3, section 2). By contrasting the regression coefficients (in this case the raw regression coefficients for Reading Comprehension time and total reading time), one can see that the negative pull is much stronger for Reading Comprehension. So the inference can be developed that the Reading Comprehension part of the CAI curriculum is the least useful to students already proficient in English. For the latter, the most valuable approach seems to be through Language Skills (LS).

Table 5.3

Regression of 1984 LAB Scores on Time Investment in CAI

Variables \ Statistic	R^2	b	F	N
LAB Pretest	.57	1.10	32.55*	
Total CAI time	.15	- .71	7.10*	
Combination	.72		16.67*	16

Transfer of Skills. Because of the very limited sample available, the study of skills transfer is tentative, exploratory, and limited to the Spanish-speaking students. The results are summarized in Table 5.4. The coefficient obtained for vocabulary, although positive, was not statistically significant, i.e., different from a chance factor. The same thing can be said for Reading Comprehension in Spanish. Thus, it can be inferred that at the primary grade level the gains on the CAI do not immediately lead to gains in overall academic standing; the skills acquired may be language specific, i.e., limited to English proficiency.

Table 5.4

Regression of CTBS/E Scores on Time Investment in CAI

Variables \ Statistic			R^2	b*	F	N
Vocabulary	Voc.	Pretest	.16	- .95	.03	
		CAI	.49	1.25	4.14	
		Combination	.65		2.74	10
Comprehension	RC	Pretest	.62	.54	4.02	
		CAI	.04	.27	.41	
		Combination	.66		2.97	10

5.3.2.2 Intermediate Grades

Program Effectiveness. The data to support the claim of effectiveness of the program in grade six was obtained from forty-four students, 28 of whom received CAI instruction for the entire year. As one can see from Table 5.5, the computer-assisted instruction had a positive and significant impact on students' proficiency in English (b = 3.75). After controlling for possible differences in initial achievement, 5 percent of the variance in the LAB performance can be attributed to participation in the program. To put it in more practical terms, the students who received CAI instruction achieved an average score of 3.75 points higher than did those who were not part of the program.

Table 5.5

Regression of 1984 LAB Scores on CAI Participation

Statistic / Variables	R^{2**}	b	F	N
LAB Pretest	.50	.64	41.96*	
CAI	.05	3.75	4.72*	
Combination	.55		25.07*	44

* p_2 .05
**R^2 change

Program Efficiency. While the main program objective was attained, it is important to establish how well the instructional sequence has been managed. The evidence gathered (see Table 5.6) suggest the presence of some cross currents at this grade level. Indeed, the near zero regression coefficient indicates that the benefits achieved were not commensurate to the amount of time devoted to CAI tasks; all participants did equally well

regardless of the length of exposure to the program. What may be responsible for that pattern? To elucidate the point (and rule out the possibility of a regression effect), the relationship between the LAB pretest and the CAI time was also studied. The correlation observed was equal to -.37. So it is clear that the students initially least proficient in English did spend the most time on the computer thus earned larger returns. However, further analysis revealed that the negative relationship was more reflective of RC (-.37) than LS (+.33). This means that there were some differences in CAI curriculum assignments based on pretest scores. Consequently, it would be more informative to study each curriculum segment separately. In an attempt to identify their respective impact, the LAB posttest scores were regressed on various time factors corresponding to the different components of the curriculum (see Table 5.6, section 2). By contrasting the regression coefficients (in this case the raw regression coefficients for Language Skills, Reading Comprehension time and Total Reading time), one can see that the pull is much stronger for Reading Comprehension. So the inference can be developed that the Reading Comprehension part of the CAI curriculum is the most useful to students.

Transfer of Skills. Because of the very limited sample available, the study of skills transfer is tentative, exploratory, and limited to the Spanish-speaking students. The results are summarized in Table 5.7. The coefficient obtained for vocabulary is positive and statistically significant, i.e., different from a chance factor. The same thing can be not said for Reading Comprehension in Spanish. Thus it can be inferred that, at the intermediate grade level, the gains on the CAI do have some limited specific impact on overall academic standing.

Table 5.6

Regression of 1984 LAB Scores on Time Investment in CAI

Statistic / Variables	R^{2**}	b	F	N
LAB Pretest	.38	.65	18.34*	
Total CAI time	.04	.24	1.67	
Combination	.42		9.23*	28
LAB pretest	.38	.66	22.04*	
Time in RC	.08	.53	4.24*	
Time in LS	.01	.40	.15	
Combination	.47		11.32*	28

*$p_2 < .05$
**R^2 change

Table 5.7

Regression of CTBS/E scores on time Investment in CAI

Statistic / Variables			R^{2**}	b	F	N
	Voc	Pretest	.22	- .24	7.58*	
Vocabulary		CAI	.30	.61	8.63*	
		Combination	.52		7.57*	17
	RC	Pretest	.26	- .19	3.58*	
Comprehension		CAI	.08	.21	1.76	
		Combination	.34		3.70*	17

*$p_2 < .05$
**R^2 change

5.3.2.3 Advanced Elementary Grades

Program Effectiveness. The data to support the claim of effectiveness of the program in grades seven and eight were obtained from thirty-one students, nineteen of whom received CAI instruction for the entire year. As one can see from Table 5.8, the computer assisted instruction did not have a positive and significant impact on students' proficiency in English (b = .005). After controlling for possible differences in initial achievement, no percentage of the variance in the LAB performance can be attributed to participation in the program. To put it in more practical terms, the students who received CAI instruction did not achieve an average score higher than did those who were not part of the program.

Table 5.8

Regression of 1984 LAB Scores on CAI Participation

Statistic / Variables	R^{2**}	b	F	N
LAB pretest	.30	.67	11.60*	
CAI	.01	.09	.03	
Combination	.31		6.56*	31

*p=.05

**R^2change

Note. Because the program was not effective at this grade level, questions about efficiency or skills transfer could not be pursued.

5.3.2.4 High School

Program Effectiveness. The data to support the claim of effectiveness of the program in grade nine was obtained from sixty-two students who received CAI instruction for the entire year. As one can see from Table 5.9, the computer assisted instruction had no significant impact on students' proficiency in English (beta=-.005). After controlling for possible differences in initial achievement, no percentage of the variance in the LAB performance can be attributed to participation in the program. To put it in more practical terms, the students who received CAI instruction achieved an average score no higher than did those who were not part of the program.

Table 5.9

Regression of 1984 LAB Scores on CAI Participation

Statistic / Variables	R^{2**}	b	F	N
LAB Pretest	.13	.30	8.98*	
CAI	.00	-.005	.002	
Combination	.13		8.98*	62

*$p < .05$

**R^2 change

But, as mentioned earlier, the emphasis at the high school level was on computational rather than verbal skills. So the most important criterion to look at, for this subgroup, is achievement in mathematics. As can be seen in Table 5.10, no significant difference in total math was observed between the group which took CAI and the group which did not. If anything, participating students even tended to score lower on the test (2.9 NCE points approximately) than those who were not selected for the program. So, the computer-assisted instruction was not very effective for the 9th grade LEP students.

Table 5.10

Regression of CTBS/E Total Math Score on CAI Participation

Statistics / Variable	R^{2**}	b	F	N
Math pretest	.07	.24	.89	
CAI	.01	-2.89	.14	
Combination	.08		.47	23

**R^2 change

Note. Because the program was not effective at this grade level, questions about efficiency or skills transfer could not be pursued.

APPENDIX A

EVALUATION MODELS

Evaluation Models

Two evaluation designs were used to assess the effects of the computer-assisted instruction program. The regular and enrichment components were evaluated by means of the analysis of covariance model for both reading and math. The bilingual component was evaluated by means of a multiple regression analysis. Each of these models is described below.

Analysis of Covariance (ANCOVA)

The analysis of covariance model compares the performance of program participants at the end of the year to that of a comparison group of nonparticipants; if participants show a higher level of achievement, on the average, compared to nonparticipants, then the program may be said to have been effective in improving achievement.

The comparison of the average performance of participants and nonparticipants is not made on their simple averages, however, but on their adjusted averages. This adjustment is made on the basis of students' pretest achievement scores, which are called the covariate. By adjusting the group averages, we remove the effects of prior ability, and are left with a purer measure of the effects of the program on students' achievement.

The analysis of covariance presumes that the effect of the program is uniform for all students, that it does not benefit some types of students more than others. (This is termed the homegeneity of regression assumption.) It is possible, however, to test whether this assumption is met,

and, if not to identify the type of students for whom the program is most beneficial.

Multiple Regression Analysis

The multiple regression technique aims at measuring variations in a group's performance that can be legitimately and significantly related to some characteristics of that group. It allows one to determine whether each of these characteristics, often called predictors, is itself relevant to skill development in a certain area.

The technique is called multiple regression because it rests on the premise that performance in any given area is often dependent not one one, but several (multiple) characteristics simultaneously. And since the characteristics or qualities of a person or a group are rarely independent from one another, the technique provides the means to adjust for such overlap. So what one obtains from the analysis is the net effect or significance of each characteristic or predictor.

In applying the technique for this evaluation, the characteristics considered as predictors were: previous achievement, participation in the CAI program, length of participation in various components of the program. The criteria of performance were scores on the Language Assessment Battery (LAB) and the CTBS/Espanol.

Participation in the CAI program is of course the key factor here. Whenever it is significant and positive, one may conclude that the program is effective and of help to student academic development.

APPENDIX B

COMPREHENSIVE TESTS OF BASIC SKILLS

COMPREHENSIVE TEST OF BASIC SKILLS

1. Comprehensive Test of Basic Skills - Level C (Grade 1)

Word Attack - 30 items tap students' understanding of word forms and structural word parts. The student must identify either initial or final consonant sound, initial or cluster digraph sound, and the medial vowel sound in orally presented words. Recognition of sight words is also measured.

Vocabulary - 25 items measure the students' ability to identify same meaning words and unfamiliar words in context. Students' ability to identify the word associated with an orally presented category or definition is also measured.

Reading Comprehension - 25 items tap students' comprehension of sentences and stories. For some items students are required to identify a picture that illustrates the meaning of a written sentence. For other items, pupils are required to identify details and ideas in written passages.

Mathematics Computation - 20 items measure computation skills in addition and subtraction of whole numbers.

Mathematics Concepts and Applications - 25 items tap students' understanding of such mathematics concepts as numeration, problem solving, geometry, and measurement units.

2. Comprehensive Test of Basic Skills - Level C

Subtest	Number of Items
Word Attack	30
Vocabulary	25
Reading Comprehension	25
Mathematics Computation	20
Mathematics Concepts and Applications	30

3. Comprehensive Test of Basic Skills - Level D (Grade 2)

Subtest	Number of Items
Word Attack	40
Vocabulary	25
Reading Comprehension	25
Mathematics Computation	20
Mathematics Concepts and Applications	30

(See description under Level C. For the mathematics concepts and applications subtest, geometry is added to the list of concepts measured.)

4. Comprehensive Test of Basic Skills - Level E (Grade 3 and 4)

Word Attack - 35 items measure students' ability to identify diphthongs or variant vowel sounds, initial or final cluster or digraph sounds. Also measured are recognition of sight words, syllables, root words, compound words, and contractions.

Vocabulary - 30 items measure same meaning words, multimeaning words, multimeaning words and unfamiliar words in context.

Reading Comprehension - 30 items tap students' understanding of reading passages. Their ability to extract details, analyze characters, identify main ideas, and draw conclusions from passages. Items also test students' ability to differentiate between fantasy and reality.

Mathematics Computation - 36 items measure students' computation skills in addition, subtraction, multiplication and division of whole numbers.

Mathematics Concepts and Applications - 40 items measure the understanding of specific concepts dealing with numerating number sentences, number theory, problem solving, measurement, and geometry.

5. Comprehensive Test of Basic Skills - Level E

Subtest	Number of Items
Word Attack	35
Vocabulary	30
Reading Comprehension	30
Mathematics Computation	36
Mathematics Concepts and Applications	40

6. Comprehensive Test of Basic Skills - Level F-J (Grades 5-12)

Subtest	Number of Items
Vocabulary	45
Reading Comprehension	45
Mathematics Computation	40
Mathematics Concepts and Applications	40

See description under Level E for vocabulary and reading comprehension. Number of items and difficulty level differ and the word attack subtest is not included at these levels. The mathematics computation subtest includes 40 items that measure the operations of addition, subtraction, multiplication and division. Depending on the level of test, content includes whole numbers, decimals, fractions, integers, algebraic expressions, exponents and percents. The mathematics concepts and applications subtests measure the same specific skills identified for Level E, but the number of items and their difficulty level differ.

APPENDIX C

DESCRIPTION OF COMPUTER-ASSISTED INSTRUCTION (CAI) CURRICULUM USED IN THE NEWARK SCHOOL SYSTEM

Basic Reading (BR) provides individualized drill and practice in second grade reading skills. The content consists of vocabulary, syntax (structure) and varying prose forms or modes of discourse, focusing on narrative and descriptive modes. Students read sentences, stories and paragraphs. Basic Reading consists of six strands, or sequences of exercises, which are organized into classes (groups of exercises) arranged in order of difficulty.

Reading, Grades 3-6 (RD) provides the remedial reader with individualized drill and practice exercises in 5 reading subskills: analysis of word structure, vocabulary, literal and interpretive comprehension of written prose, and work-study skills. There are two sections in the curriculum. The first is Basic Sentences, consisting of two to five word sentence items designed to familiarize students with the most common vocabulary and sentence patterns in the English language. The second consists of five strands which represent the 5 subskill areas outlined above.

Reading for Comprehension (RC) is a drill and practice reading curriculum for average readers in grades 3 through 6. There are five subskill strands, (the same reading subskills described in RD above) and a sixth strand, called Paragraphs, in which students can integrate some of the subskills as they read an entire paragraph and answer questions.

Critical Reading Skills (CRS) is a higher level curriculum in that it requires more than just decoding skills; it requires the ability to apply critical reading skills to subject matter. The process of reading becomes elevated to the art of critical thinking. There are two parts to the curriculum. One is a vocabulary section in which words are presented 3 times each, so that students get a feel for the variety of connotations and syntactic usages of words in English. The second contains reading passages drawn from several subjects (e.g., literature, science, history) and students are assessed to determine such things as: motivation of a character, correct sequence of steps, the relationship of ideas, etc. This section also provides tutorial messages after wrong answers, which are designed to help students understand the questions, and explain where they went astray in either reading or reasoning.

Fundamentals of English (FUN) provides both tutoring and practice in correcting several common problems of written standard English. The course is appropriate for students at the junior high school level or above who need remedial work in some of the basic conventions of the language. The course is divided into six chapters: sentence elements, sentence fragments, run-on sentences, using verbs correctly, double negative and subject-verb agreement.

Language Arts Grades 3-6 (LS) stresses language usage problems instead of grammar. It also offers supplementary lessons for students with special language problems, including students for whom English is a second language. The program is divided into two courses, Language Arts Strands and Language Arts Topics. The Language Arts Strands course has eight strands, each covering one general subject area in ascending order of difficulty (principal parts of verbs, verb usage, pronoun usage, subject-verb agreement, mechanics, sentence structure, modifiers, and contractions, possessives and negatives). Language Arts Topics contains 90 topics, a topic being a group of lessons on a single subject. The topics cover such subjects as: contractions, verb usage, plurals, sentence structure, etc. Each lesson has two parts: one explains or gives examples of the lesson concept, and the other contains items which give the student practice in working with the concept.

Mathematics, Grades 1-6 (MA) is a highly individualized drill and practice program, covering 14 different strands or content areas. Each strand contains a set of exercises that range from easy to hard. The strands include horizontal and vertical addition, subtraction and multiplication, equations, measurement, division, fractions, decimals, number concepts, laws of arithmetic and negative numbers.

Mathematics, Grades 7 and 8 (MM) uses a strand structure to provide drill and practice in material covered in conventional seventh and eighth grade mathematics courses. The nine strands are: positive integers, fractions, decimals, percent, negative numbers, equations, inequalities, measurement and number theory.

Problem Solving, Grades 3-6 (PS) gives elementary school students practice in solving story problems. Here, students are to apply their computational skills to everyday situations. The program is divided into seven strands, each with exercises arranged in order of increasing difficulty. The content areas are: how many, money, mystery numbers and age problems, measure, number systems, time, rate & distance, and geometry. This curriculum provides tutorial messages when students need help.

Math Enrichment Modules, Grade 7 & 8 (EM) includes subjects not ordinarily covered in seventh and eighth grade mathematics courses and is appropriate for junior high students working at grade level. There are six content areas or modules: sets, geometry, statistics, probability, logic, and functions and graphing. If a student answers an exercise incorrectly, the program gives a tutorial message to help solve the problem.

Introduction to Algebra (ALG) teachers basic algebraic concepts and techniques for solving equations. An off-line textbook, which contains explanations and examples, accompanies the course. The student reads a lesson in the text and then answers questions and works exercises related to that lesson at the computer terminal. The course is appropriate for 9th grade students. When a student works an exercise incorrectly, the program tells why the answer is wrong or shows the correct procedure to use.

Adult Reading Skills (ARS) and Adult Arithmetic Skills (AAS) were designed to meet the needs of post elementary students who lack basic reading and arithmetic skills. The adult reading skills course is grouped into five strands which are the same areas covered in the Reading, Grades 3-6 course: word attack, vocabulary, literal comprehension, interpretive comprehension and work-study skills. The Adult Arithmetic Skills course has eight strands: addition, subtraction, multiplication, division, equations, fractions, measurement and decimals. The scope of this course is more limited than the elementary math courses; it provides more practice in basic skill development and has fewer problem types.

Survival Skills (SS) is a course developed to apply basic reading and mathematical skills to materials and situations in everyday life. The curriculum consists of independent modules in the areas of health and nutrition, consumer skills, employment, personal finance, using information sources, and transportation and entertainment. The course includes a textbook to be used with the computer lessons. The reading level of most of the instructions and explanations is between 5th and 8th grade.

Exploring Careers (EX) is a career guidance system which provides occupational information to students. It also helps them to determine which jobs are best suited to them, based on their interests and abilities. The job descriptions range in reading level ability from 7th go 10th grade.

APPENDIX D
GLOSSARY OF TERMS

GLOSSARY OF TERMS

BASIC	(Beginners All-Purpose Symbolic Instructional Code) A beginners' computer language which enables the user to communicate with the computer and tell it what to do.
Computer-assisted Instruction (CAI)	Refers to the use of computers as an aid in instruction, with the machine as an instructional delivery system. One learns "from" the computer.
Computer Curriculum Corporation (CCC)	A company, based in Palo Alto, California, which produces computer hardware and software. The Newark school system uses CCC equipment.
Computer Literacy	Refers to a beginning awareness of the components that make up a computer system, computer languages, the basic operations of a computer, and an introduction to the actual programming of a typical computer. One learns "about" the computer.
Correlation Coefficient	The most commonly used measure of relationship between paired facts or of the tendency of two or more variables or attributes to go hand-in-hand. It ranges in value from -1.00 for perfect negative relationship through 0.00 for no relationship or pure chance to +1.00 for perfect positive relationship.
Drill and Practice	One of the applications of computer assisted instruction which involves student use of the computer to practice and reinforce concepts and techniques that have been learned from another source.
Frequency Distribution	A tabulation of scores from high to low (or low to high) showing the number of persons who obtain each score or group of scores.
Hardware	Refers to the actual physical devices that are part of a computer system.

Maxicomputer (or main-frame computer)	The largest (room-filling) of computers which is the most powerful in terms of memory size and speed of execution. This machine is used for major tasks of data collection and analysis.
Minicomputer	The next smaller kind of computer (refrigerator size) which is also less powerful in terms of memory and speed.
Microcomputer	The smallest kind of computer. It is portable and is commonly used in schools and homes. Although its memory size and speed are not as powerful as the mini-computer, it is more than adequate for educational and personal uses.
Modem	A computer terminal which connects to a main-frame computer. The terminals in the Newark school system are modems.
Normal Curve Equivalent (NCE)	A standard score developed to have limited correspondence to percentile rankings. NCEs are equal-interval scores. They can be legitimately aggregated and averaged.
Norms	Summary statistics that describe the test performance of reference groups of pupils of various grades in the standardization group for the test.
Software	Refers to the program or instructions and data that the computer user gives to the computer.
Standardized Test	A test that is composed of empirically selected materials, has definite directions for administration, scoring and use, has data on reliability and validity, and has adequately determined norms.
Tutorial	One of the applications of computer assisted instruction in which the computer is programmed to present a lesson and to give helpful messages when a wrong answer is given. These messages may give clues as to why the answer is wrong or what procedures to follow to get the correct answer.

APPENDIX E
Companion Study:
Reading Competencies and Reading Comprehension

Introduction

Because it is a necessary ingredient for the learning of virtually every school subject, reading comprehension is probably the most important skill for academic development. Yet, it is a set of competencies that not only students have difficulty mastering, but one also that educators have not fully understood. Differences between good readers and poor readers have been documented. But this does not mean that the instructional strategies used with the good readers are necessarily the most appropriate for the poor readers. As Samuels (1976) put it "The fluent reader has mastered the subskills, combined them into higher units, so that subsequent interfacilitation of subskills does take place...So just because fluent readers are able to access the meaning in a printed page is no reason to believe that beginning readers can do the same" (page 173). What this suggests is that a better approach for studying reading comprehension is to not only develop inter-individual comparisons, but also consider intra-individual differences. This is the research plan adopted in this present work.

This study consists of two approaches to the understanding of the acquisition of reading skills: Experiment I deals with the nature of intra-individual differences in reading skills, while Experiment II deals with the nature of inter-individual differences.

Taking advantage of the monitoring capabilities of a computer-assisted instruction program, in Experiment I we set out to follow student learning of six competencies that are involved in both the acquisition and the development of reading comprehension: word attack, vocabulary, literal comprehension, interpretive comprehension, paragraph meaning, and reference skills. The objective of the analysis is to define a teaching strategy that takes into

account the level of student need in each competency, the degree of responsiveness of each competency to instructional intervention, and the extent of interfacilitation or transfer from one competency to the other. So, three sets of questions are being addressed in this study: 1) Which component of reading comprehension appears to be the most difficult for students? Which one seems the easiest? 2) Which component of reading comprehension can be most easily improved? Which one seems most resistant to change? 3) Is there an optimal order for introducing each competency so as to facilitate transfers from one to the other, and from the set to reading comprehension? In other words, is there a particular hierarchy underlying the various competencies?

In Experiment II we set out to clarify the relationship between rate of progress in the acquisition of reading comprehension and initial reading ability, in order to understand general differences between fluent and beginning readers. Three questions were addressed in this study: 1) Is rate of progress in a program of instruction in reading comprehension related to students' initial levels of ability in vocabulary and reading comprehension? 2) Do other demographic characteristics such as sex, biculturality and starting level of instruction (above or below one's chronological grade) modify the relationship between initial ability level and rate of progress? 3) What is the nature of the rate of progress: constant, positively accelerating or negatively accelerating?

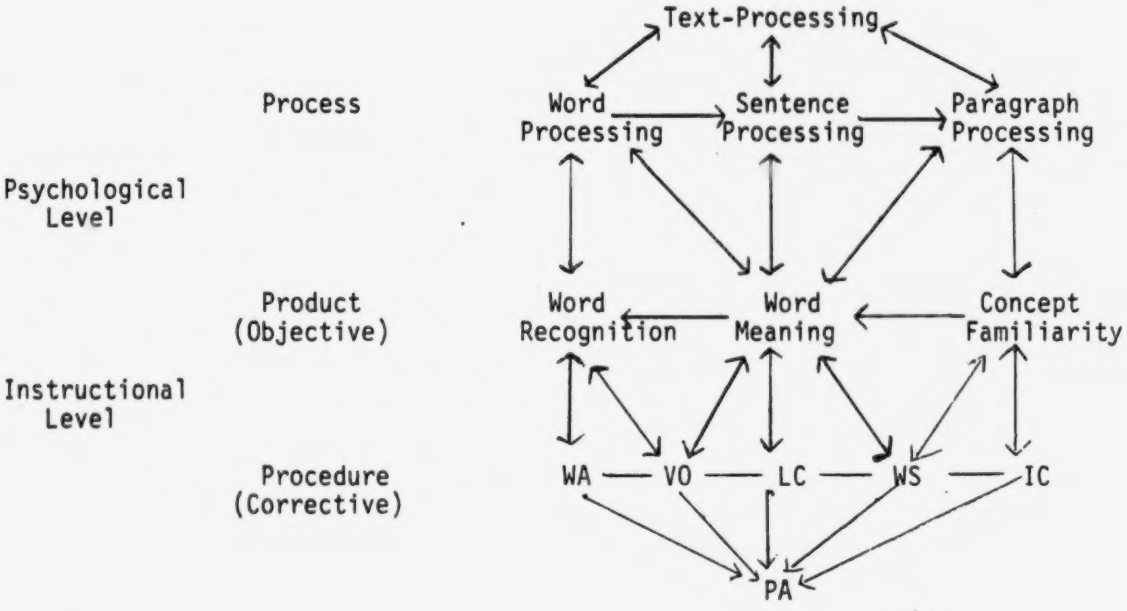
Experiment I

Theoretical Background

The analysis of reading performance into competencies can be done according to one of two models: a block model or a flow model. The first perspective evolves from the mental measurement tradition, and aims at cataloguing all the abilities necessary for the various blocks or tasks making up reading comprehension. For example, Davis (1944, 1968) identified two major components of comprehension in reading among mature readers: knowledge of word meaning and verbal reasoning. The latter component was further analyzed into five clusters: "finding answers to questions explicitly from a passage, weaving together the ideas of a passage and grasping the central thought, making inferences about the author's point of view, recognizing the tone, mood and literacy devices used, and following the structure of a passage" (pp. 8-52). This classification has served as the blueprint for reading test construction for years, and it is no wonder that the abilities identified account for about 94 percent of the variance in such tests. The shortcoming of this approach is that it does not say very much about the teaching process; one is told of the desired outcome but not how it is brought about.

The alternative more recent perspective on reading is inspired by information processing models, especially text-processing (Resnick and Beck, 1976). Here reading is seen as a (self-) directed search for meaning, and the aim is to identify the various points at which this search may be interrupted, and thus feedback may become necessary. In the model proposed by Resnick and Beck, for example, there are four possible break points. "The first such interruption is for an unrecognized word (Query 1) that necessitates the use of word-attack skills....The second interruption occurs when a word is sounded that has an unclear meaning (Query 2)...At Query 3, processing is interrupted by awareness of a sentence or clause whose meaning is not completely clear...

We come finally at Query 4, to a situation in which an entire section (paragraph, chapter) is seen as unclear...due to unfamiliarity with the concepts discussed in the text" (pp. 199-200). Based on this four-point sequence and the number of monitoring activities it may call for, an entire map of reading comprehension is developed, which includes more than 50 paths (see Appendix). It is, however, possible to streamline this map, especially if one thinks of reading skill development not as a strictly self-monitored process but as an externally guided activity. Our attempt at such streamlining has resulted in the following model.



The model links each comprehension break point to corresponding corrective procedures. Actually, the bottom-half of the figure is conceived as the instructional (mirror-)image of the psychological process described in the upper-half.

The development of each of these competencies in each student requires constant nurturing and monitoring. This calls for not only good management of

the learners but also good management of the learning. Learners' management is usually insured through the various grouping practices that occur in a school or in a classroom. Learning management according to Bloom (1976), "has to do with the cues or directions provided to the learner, participation of the learner in instructional activity, the reinforcement which the learner secures in some relation to the learning, and the corrective feedback system... which is the constant adjustment to the learner's needs" (p. 115). Such a high quality of instruction can be made uniform for a group of students through a computer-based program of learning. The computer "prestores programs, evaluates students' responses, provides feedback on these responses, and records the students' progress. Second, each student is given the opportunity to respond continually during the session and each student responds to as many questions as possible. And third, computers individualize instructional levels and pace according to each student's level of achievement, specific interests, and abilities" (Saracho, 1982, p. 204).

Even at its lowest level of sophistication, which is drill-and-practice, computer-assisted instruction has been shown to represent an effective approach to remediation, especially for disadvantaged students (Atkinson, 1974; Dorsey and Buleson, 1982; Jamison, Suppes, and Wells, 1974; Kulik, Bangert, and Williams, 1983; Martin, 1964). It must be immediately added, however, that our objective in the present project is not evaluative. In other words, we are not assessing the impact of a CAI program, we are interested in the learning rate of students. For that reason, we are not limited to a remedial group, we are examining the entire ability range. Finally, while the majority of the studies involving CAI looked so far at math achievement (which is probably most amenable to drill-and-practice), our attention is on reading comprehension.

Method

Sample - - The population under study is a group of 1,000 elementary school students in grade 2 through 6. They attend class at six Newark public schools which offer a computer-assisted instruction program as either a remedial supplement or an enrichment to the regular curriculum in reading, language arts, and mathematics. Out of this group, 94 pupils studying reading comprehension were selected. The sample includes an approximately equal number of boys and girls. Twenty-six percent of them have a bicultural background (English-Spanish or English-Portuguese). Based on their CTBS scores on the reading comprehension subtest, 17 of them can be considered mature readers (scores at or above the sixth stanine), 20 are average readers (scores at the fifth stanine), 50 are below average readers (scores on the third or fourth stanine), and 7 are designated as functional illiterates (scores at or below the second stanine).

Measurement -- The program of study was designed by CCC (Computer Curriculum Corporation) a nationally recognized developer of instructional materials. The reading comprehension course is organized into six subskills or strands including: vocabulary, word-attack, literal comprehension, interpretive comprehension, paragraph understanding, and work-study skills. A total of 9,750 items, covering a difficulty range between grade 3 and 6 are available for presentation in a drill-and-practice format. The scores derived from these items are analogous to grade-equivalents. For this study, the first set of six measures were obtained at the end of November, after a period of initial placement which afforded all students time to learn the logistic of the computer. Two months of instruction followed, and at the end of January, another assessment was made of students' competence in all six areas. The scores obtained from the computer can be considered as criterion-referenced

measures. In addition, we included a norm-referenced measure, the Comprehensive Test of Basic Skills (CTBS, 1982 edition), which was administered prior to program enrollment in the spring of 1983.

Statistics -- In the preliminary stage of the analysis, the CAI scores were validated against the CTBS scores. After assigning students to one of eight categories based on their ability level (CTBS) and their cultural background (monocultural vs bicultural), a series of one-way analysis of variance were conducted, using the nonparametric procedure known as Kruskal-Wallis. Then to answer the first research question about intra-individual differences from subskill to subskill in reading, a Friedman analysis of variance was conducted. The second question about the rate of progress in each subskill was studied using the same statistical procedure. Finally, to determine whether the set of competencies could be arranged into a skill hierarchy, a scalogram analysis was performed: on each strand, a student's score was recoded as 1 or 0, depending on whether he/she had progressed on that strand by at least .2 grade equivalent (corresponding to 2 months of instruction); then the Guttman technique for scaling was applied.

All statistical tests were interpreted at .05 level of significance.

RESULTS AND DISCUSSION

A - Validity

Measuring progress through the CAI curriculum is equivalent to an assessment of objectives mastery. These objectives, of course, need to be validated beforehand, if the assessment of student progress is to be meaningful. Scores on the CTBS reading comprehension subtest were used as the main criterion for that validation procedure. The results of the Kruskal-Wallis technique are reported in Table A1. Each table cell contains the mean rank for one of the subgroups making up the sample. The rank order may be

Table A1

Mean Ranks on reading strands for monocultural (M) and bicultural (B) students of differing ability levels

		SKILLS					
		WA	VO	LC	IC	PA	WS
Functionally Illiterates	M	11.6	11.7	13.4	10.4	12.0	13.4
	B	-	-	-	-	-	-
Below average Readers	M	36.0	36.3	35.7	36.2	36.8	37.2
	B	27.5	27.4	27.3	27.7	27.3	25.9
Average Readers	M	63.8	63.8	64.0	64.5	64.5	62.9
	B	63.8	62.3	63.6	61.9	57.8	61.9
Mature Readers	M	77.4	77.0	76.1	76.7	78.4	78.2
	B	-	-	-	-	-	-
Chi-square		57.9	56.8	56.5	57.9	55.6	56.0

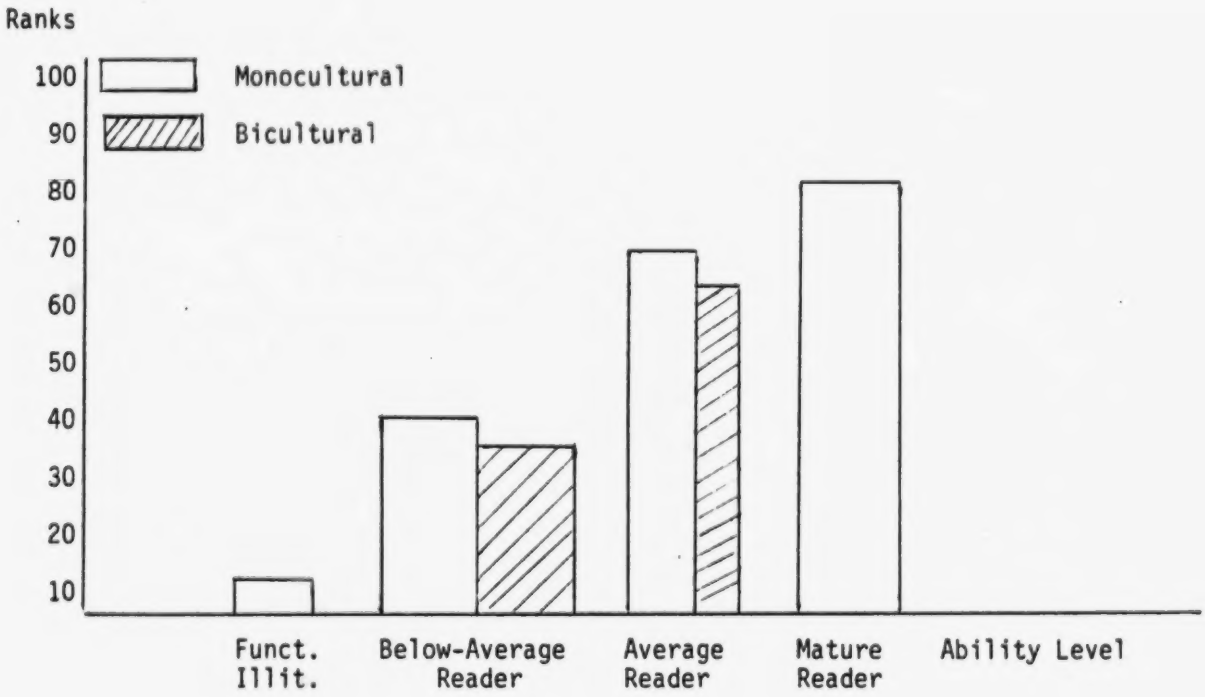


Figure 1

Mean ranks on literal comprehension for monocultural and bicultural students of differing ability

interpreted as a local percentile distribution, and is pretty consistent from subskill to subskill. One can see that students considered to be mature readers, by CTBS standards, average a mean rank of 77.44 on the CAI curriculum, which would correspond to the 7th stanine. At the other end of the spectrum, the students deemed functionally illiterate, by CTBS standards, barely make it beyond the 11th percentile on the local distribution, which corresponds to the top of the second stanine. When the chi-square values were transformed into correlation coefficients, they were all around .85. In examining more closely the table's content, one is likely to be struck by two points:

1 - When one compares the various ability groups to one another, one notices that the most striking differences are within the low-ability range. In other words, while there is only a modest difference between a mature reader and an average reader, there is quite a significant one between the latter and the below-average reader. This difference is as great as the one observed between the below-average reader and the functionally illiterates (see Figure 1). So Samuels (1976) may have been right in suggesting that, because of skill interfacilitation, the poor reader is in a qualitatively different situation from that of the good reader.

2 - The second point has to do with the socio-linguistic factor of biculturalism. While the monocultural students are distributed along the entire spectrum of ability, the bicultural pupils are concentrated in the middle range, i.e., they are either average or below-average readers. Though none of them has reached full maturity in their use of English, none belongs to the illiterate category either. For the average readers, furthermore, the performances are comparable, regardless of cultural background. But among the below-average readers, the bicultural seem to have more difficulty than the

monocultural. As a result, if one contrasts the average reader with the below-average reader within each cultural group, one observes that the difference in skill mastery is greater for the bicultural group than it is for the monocultural group. All this suggests that bilingualism/biculturalism does not hamper the acquisition of basic communication skills in English, it might simply slow down the development of those skills, making it difficult for young bicultural pupils to excel on any verbally-loaded tests.

B - Student Needs

Let us turn now to our first research question concerning the level of student need in the various reading competencies. The results of our analysis, reported in Table A2, indicate that the weakest link is in reference skills, as measured by the work study strand. Of the skills that are traditionally assessed in reading comprehension subtests, the most problematic is interpretive comprehension. That is followed by vocabulary and paragraph understanding. Finally, the two strongest areas deal with word-attack and literal comprehension. When the measures were obtained again in January, the skill rank-order remains practically the same, except for a sharper differentiation between vocabulary and paragraph understanding. This degree of replication underscores the stability or reliability of the ordering.

The validity of the ranking may not be as evident. One would expect, for instance, to see the word attack strand and the work study strand in relatively close position, since both skills partially focus on letter relations. Similarly, one would expect paragraph understanding to show the highest difficulty index, since it is generally believed (and the CAI curriculum was designed in that perspective) that it is where students have to integrate all the other basic subskills. The results say differently. Such departures open the door for a re-evaluation of the relationships among the various strands.

Two concepts seem sufficient to define these relationships and empirically account for the departures. One has to do with the level of information processing, the other with the level of comprehension. There are two levels of information-processing: a) recoding, which is the building of symbols into meaningful units (like letters into words); b) retrieval, which is the selection of meaningful units from a context (like finding the title of a passage). Comprehension, on the other hand, can be seen as having three levels: a) recognition, which is simply the identification of a term; b) denotation, which calls for providing a direct, explicit equivalent for a term; c) connotation, which requires referential skills, i.e., the placing of a term within a context of associated ideas. Combining the two concepts of processing level and comprehension level illuminates the relationships among the six reading competencies, as can be seen in the chart below:

		Level of comprehension		
		Recognition	Denotation	Connotation
Level of information processing	Recoding	Word Attack	Vocabulary	Work-Study skl.
	Retrieval	Literal comp.	Paragraph und.	Interpretive comp.

C - Student Responsiveness

One could consider the entire computer-assisted instruction program as an extensive feedback system. The idea has been suggested by Bloom (1976). In that perspective, it becomes possible to determine exactly which skill is most sensitive to that type of feedback (drill and practice) and maybe to instructional intervention in general. Operationally, this question requires an assessment of the gains realized by students in each strand.

The results of such an analysis are reported in Tables A3 and A4. From an examination of the first table, one will retain the following points:

Table A2

Comparative difficulty level of each reading competency
(Lowest rank = 1; highest rank = 6)

	WA	VO	LC	IC	PA	WS
Nov. performance	4.6	3.4	4.0	2.9	3.5	2.6
Jan. performance	5.0	3.6	4.6	2.7	2.8	2.3

Chi-square (Nov.) = 70.9 Chi-square (Jan.) = 174.8

Table A3

Comparative growth in each reading competency
(Scores are ranks. Lowest = 1; highest = 6)

	GWA	GVO	GLC	GIC	GPA	GWS
Primary grades	4.7	3.5	4.4	2.9	2.8	2.7
Middle school	4.9	3.8	4.6	2.9	2.6	2.3
Total group	4.9	3.7	4.5	2.9	2.6	2.4

Table A4

Spearman correlations of CTBS reading comprehension subtest with:

	Nov. CAI scores	Jan. CAI scores	2-mo. gain scores
VO	.855	.869	-.159*
LC	.845	.858	-.210
PA	.859	.871	-.202
IC	.857	.872	.-129*

*not significant at .05 level

a) The ordering and the clustering of skills reflect the pattern already observed for the analysis of needs (preceding section). Indeed, the largest gain was achieved in word-attack and literal comprehension; vocabulary occupies an intermediate position, while paragraph understanding, interpretive comprehension, and work-study skills form a cluster that seems rather resistant to change. What is evidenced by that pattern is that students make their biggest advances where they are the strongest. In other words, success (even in relative terms) breeds success. This also brings to mind the possibility of a threshold phenomenon, i.e., that a certain amount of strength is necessary before progress can be noticeable in a particular academic area.
b) Comparing the pattern for primary school children to the one obtained in the middle school we notice that while the skill ordering is the same, the actual ranks tend to differ. In word-attack, vocabulary and literal comprehension, the ranks are higher for middle grade pupils; in interpretive comprehension, the two groups are comparable; in paragraph understanding and work-study skills, the ranks are better for the primary grade students.

What is to be understood from that kind of group-to-group variations? One may look for an explanation in time management: in the middle grades, the bulk of computer-time may be devoted to the basic subskills (word attack, vocabulary, etc.) rather than the more advanced competencies. On the other hand students in the primary grades may get to spend a little more time on the advanced skills than it is possible in the middle grades. The differences in time on tasks is plausible given the differences in ability. Indeed, one has to keep in mind that the younger group includes a good number of second-graders working on a curriculum designed for the third-to-sixth grade level; this says something of their ability; in grades 5 and 6, meanwhile, the program is remedial in nature.

But rather than limiting ourselves to speculations about the differential impact of ability on subskill development, we have initiated that kind of assessment. More will be said later about the relation between ability and academic gain in general (see experiment #2). For now, the focus is on four of the reading competencies which are directly involved in "meaning detection" or comprehension per se. The gains and the scores on each of these competencies were correlated to the scores on the CTBS reading comprehension subtest. The results are summarized in Table A4. Given the correlations for the gains, it is clear that the rate of progress in literal comprehension and paragraph interpretation is greater for low-ability students than it is for the more able ones. As for vocabulary and interpretive comprehension, the gain rate is the same regardless of ability. So, at least in some areas, the students with the greatest needs (low CTBS performance) seem to be benefiting from the program more than their stronger peers. This improvement, however, is insufficient to alter the rank ordering in the total group. Indeed, the negative pattern of coefficients obtained with the gain scores stands in sharp contrast with the high and positive correlations observed for both the November and the January performances. The more able pupils may be moving at a slower pace, but they still maintain their standing. The lesson to be learned from all this is that responsiveness in academic competencies can be at variance with competitiveness. To put it differently, when the instructional program is uniform, responsiveness signals greater skill mastery but not necessarily greater competitiveness.

D - Skill Hierarchy

The information gained so far about students' needs and responsiveness in various reading competencies is necessary but not sufficient to develop an instructional strategy. To advance that development, one needs to know

Table A5

Heirarchical arrangement of reading competencies

SKILLS

SCALE SCORES	GPA F	GPA P	GIC F	GIC P	GVO F	GVO P	GLC F	GLC P	GWA F	GWA P	N Total	Cum. %
5	0	21	0	21	0	21	0	21	0	21	21	22%
4	3	5	4	4	0	8	1	7	0	8	8	31%
3	2	0	2	0	0	2	0	2	0	2	2	33%
2	10	1	9	2	10	1	1	10	3	8	11	45%
1	12	0	11	1	11	1	12	0	2	10	12	57%
0	40	0	40	0	40	0	40	0	40	0	40	
Sum	67	27	66	28	61	33	54	40	45	49	94	100%
%p/Col		72%		86%		94%		100%		100%		
%c/Tot		29%		30%		35%		43%		52%		

P = Pass (Gain $\geq$ .2 GE) F = Fail (Gain $<$ .2GE)
Coefficient of Reproducibility = .953
Minimum marginal reproducibility = .632
Coefficient of scalability = .873

whether there is an optimal order for introducing each competency. In our judgement, the optimal order is the one that best facilitates transfer from subskill to subskill. That is best evidenced through a skill hierarchy. A scaling technique was applied that enabled us a) to separate the pupils whose rate of progress is lower than expected (less than .2 grade-equivalent) from those whose development is satisfactory, b) to establish, based on the difficulty index, the ideal position of each competency in the learning sequence. The results are presented in Table A5 and in Figures 2 and 3.

First of all, we will point out that 43 percent of the participating students are not progressing as expected (less than .2 point of gain in 2 months of instruction). Fifty-seven percent have gained a minimum of two months in at least one area; 45 percent have reached the same criterion in at least two strands; 33 percent have shown similar achievement in at least three skills; 31 percent have done it in four areas; 22 percent have progressed at or beyond the expected level in every competency (see Figure 2). Narrowing the focus on each specific strand, we notice that 27 students were able to achieve a gain of at least .2 GE in paragraph understanding; of those 72 percent or 21 have shown a similar gain in all other areas. Twenty-eight student progressed by .2 GE in interpretive comprehension; of those 86 percent have maintained the same level of achievement in all areas except paragraph understanding. For vocabulary, the number of pupils showing a .2 gain moves up to 33; of those 94 percent have been equally successful in literal comprehension and word-attack, but not in paragraph understanding and interpretive comprehension. With literal comprehension, 40 pupils met the success criterion; 100 percent of them evidenced equal strength in word-attack, but not on any other strand. Finally, 49 out of the 94 students were able to improve their word-attack scores by .2 GE.

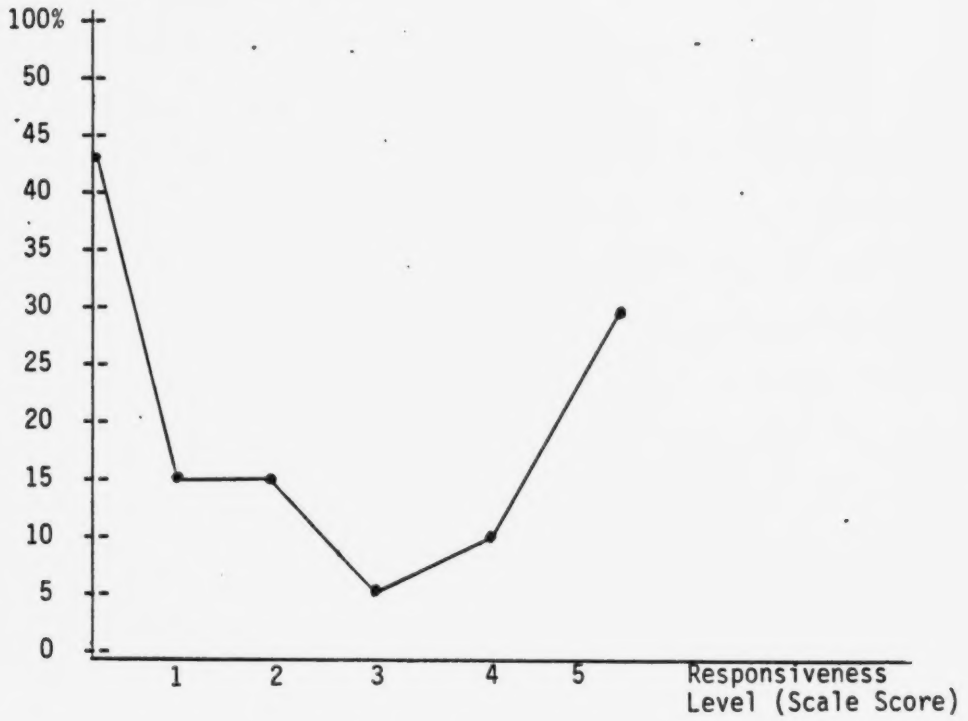


Figure 2

Variations in degree of responsiveness shown by students

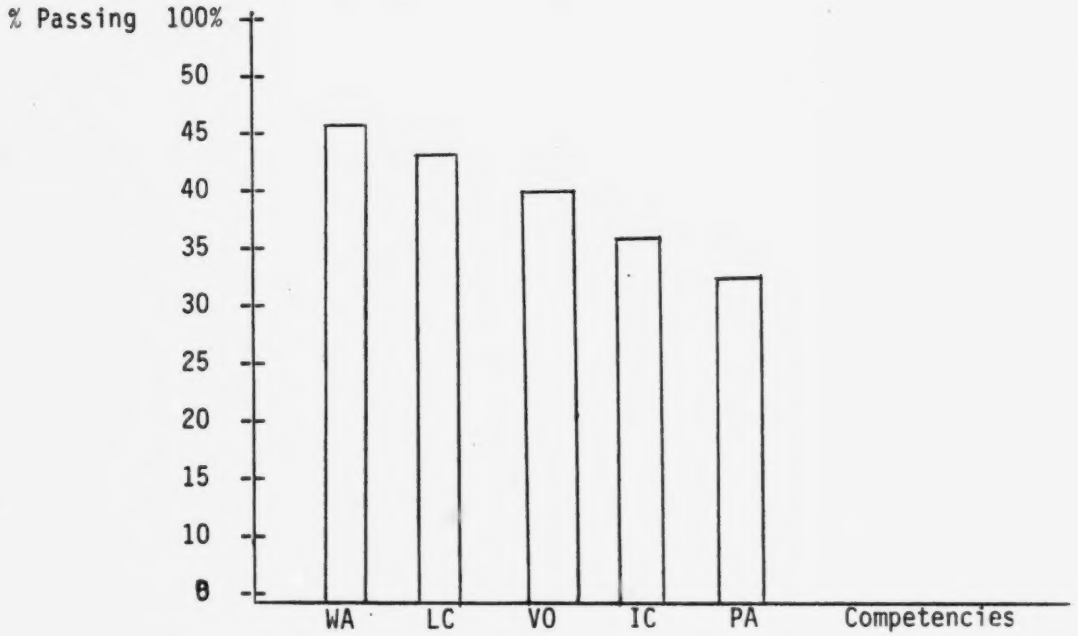


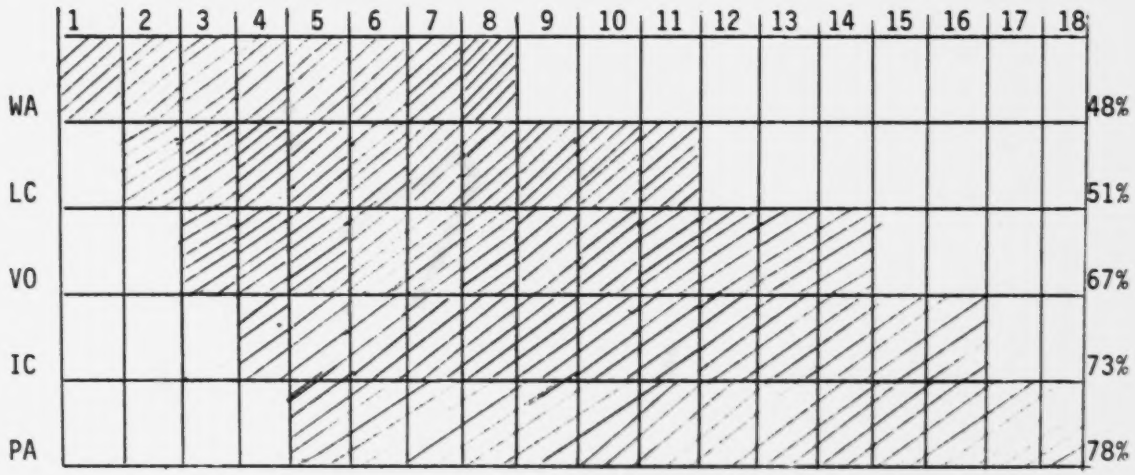
Figure 3
Percent of students gaining .2 or more GE
on each reading strand

All this leads to a scalability coefficient of .87 and a reproducibility index of .95, clearly demonstrating that the five major strands fall along what may be called a comprehension continuum which has word-attack at its lower end and paragraph interpretation at its top (see Figure 3). Of course, basing the scaling on difficulty level partially duplicates the findings mentioned in previous sections of this report. But some new, very significant point can be highlighted. One must note, for instance, that paragraph understanding which in terms of students needs occupies only an intermediate position (see section #1), has now moved to the top of the chart. For that kind of variation to occur, the 21 pupils successful on that strand must have scored quite high on it. This in turn implies that of all the subskills paragraph understanding is the one with the greatest discriminating capability.

The fact also that paragraph understanding takes precedence over interpretive comprehension shows that, while the great majority of students who can handle the former strand have also strength in the latter, the ability to do verbal reasoning (interpretive comprehension) does not automatically translate into strength in paragraph reading. So, the whole is not necessarily a sum of the parts. Something else may be at work here. We tentatively identify this "something" as context, and speculate that the difference between the fully mature reader and the uncertain reader is not just in the ability to combine subskills, but also in their use of the context to derive the meaning of (unclear) words and sentences. This notion is close to an idea advanced by Holmes and Singer (cited by Athey, 1976) after finding that "the ability to use contextual clues to fill in gaps in a passage is a significant variable in distinguishing between good and poor readers at all grade levels" (pp. 6-46).

One application of all these findings is in the area of instructional time allocation. In his/her management of the reading class, a teacher has to allocate time to each strand in direct proportion of student needs and of the strand's facilitative value. For instance, since 70 percent of the students experience difficulty with interpretive comprehension versus 48 percent in word-attack, less time is needed on the latter subskill. How much less time? Approximately 40 percent less. Over the entire year, assuming 180 days of instruction, that approach would lead to the following reading calendar:

Time Management Grid



*Each column represents 10 days of instruction

Experiment II

Theoretical Background

Many longitudinal studies have indicated that there is a substantial relationship between prior knowledge and subsequent achievement (Bloom, 1964; Bracht and Hopkins, 1972; Hicklin, 1962; Payne, 1963). The correlation of initial reading level and later reading achievement varied from .60 for primary to secondary grades to as high as .90 for adjacent grades; initial ability thus accounted for 36 percent or more of the variance in subsequent achievement, even several years later.

Bloom (1976) has pointed to the sequential nature of learning as one of the factors involved in this process. Since successive tasks build on prior knowledge, the earliest learning tasks are the most critical; nonmastery at an early level of schooling may affect learning of all subsequent tasks. Particularly important predictors of later achievement are vocabulary skills for reading achievement in the early grades and reading comprehension skills which affect the learning of all subjects involving reading.

Individual differences in learning are not felt to be inherent in the learner but the result of environmental factors and experiences, including econommic disadvantage (Bloom, 1976). These early differences may become magnified as the child progresses through the educational system. An important element of this magnification process is felt to be group instruction, which does not take into account individual needs, but presumes that all group members begin with the same level of knowledge. Such an assumption is erroneous and may serve to exaggerate the differences among students as those possessing the requisite skills continue to learn while those needing special help fall further behind (Bloom, 1976).

It has been suggested that the solution to this problem lies in an individualized approach to education (Bloom, 1976; Carroll, 1963). According to this view, if learning conditions are equal, students with initially higher ability levels will tend to show greater gains in achievement; but if learning is tailored to individual needs, then most students will achieve mastery and the influence of prior ability on subsequent achievement will diminish.

As noted above, a computer-assisted program of instruction has the advantages of providing immediate feedback to the learner and of tailoring instruction to meet individual needs. These may be important aspects of its success as an approach to remediation (Atkinson, 1974; Kulik et al., 1983; Litman, 1973; Martin, 1964). Therefore, we wished to investigate the relationship of gains in such an individualized instructional program in reading to prior knowledge in two areas of reading skills. If individualized instruction does in fact reduce the gap between initially high and low achievers, then we would expect that gains in such a program would show a weaker relationship to initial ability levels than those found in previous research on regular classroom instruction.

Method

Sample. The sample was drawn from a population of 1,000 elementary school students attending six Newark public schools offering a computer-assisted instruction program. Seventy-seven students studying reading comprehension were selected. The sample consisted of approximately equal numbers of boys and girls; about 25 percent of the sample were of bicultural backgrounds (English-Spanish). Students represented a wide range of reading ability based on their standardized test scores prior to participation in the CAI program.

Measurement. Students were enrolled in the Reading for Comprehension

course designed by the Computer Curriculum Corporation of Palo Alto, California. The course covers six subskill areas of vocabulary, comprehension, and work-study skills in a drill-and-practice format. The difficulty level of the course ranges from grade 3 through grade 6. Scores are provided in the form of grade-level scores for each strand and for the course average and as monthly gain scores. For this study, gain scores were obtained for the months of November, December, and January, and for the total three-month period; initial course average prior to instruction was also obtained. Gains were assessed in the form of a ratio of gain to time on task for each month and for the three-month period; initial course average was assessed in ration to the student's chronological grade. Initial reading ability was assessed by performance on the Comprehensive Tests of Basic Skills (CTBS), Form U, administered in May 1983 prior to participation in the program. Standardized test scores were normal curve equivalents.

Procedure. In order to answer the first and second research questions, dealing with factors related to progress in a program of reading instruction, multiple regression procedures were used; total gain in reading comprehension relative to total time on task was regressed on initial starting level relative to chronological grade, sex, biculturality, and CTBS vocabulary and reading comprehension scores (representing initial reading ability before program participation). The significance of each predictor was assessed at the .05 level of significance.

The third research question, dealing with the nature of the rate of progress in reading, was analyzed by computing the ratio of monthly gain to monthly time on task for November, December, and January. These ratios were compared in order to assess the magnitude of gain relative to time on task for each month and the fluctuation of these gains over time. For this part of the analysis, complete data were available for grades 5 and 6 only.

Results

Table B1 shows the results of the regression of rate of progress in reading on relative initial starting level, sex, biculturality, and prior vocabulary and reading comprehension ability. The variable set accounted for 21 percent of the variance in rate of progress in reading. All predictors other than prior reading comprehension level contributed significantly to the regression.

Relative initial starting level in the reading program accounted for 2.5 percent of the variance in rate of progress; the beta weight for this variable

Table B1

Regression of Rate of Progress in Reading on Initial Starting Level, Sex, Biculturality, and Prior Reading Scores

Predictor	R	R^2	R^2Change	Beta	F
Initial Starting Level	.158	.025	.025	-.438	6.317***
Sex	.325	.106	.081	-.325	8.726***
Biculturality	.373	.139	.034	.177	2.680*
Vocabulary	.459	.210	.071	.387	4.733**
Reading Comprehension	.459	.210	.0001	.020	0.012

n=77
*p <.05
**p <.01
***p <.001

was negative, indicating that students with lower initial starting levels tended to make better progress in the program.

Sex of student accounted for 8.1 percent of the variance in rate of progress; the beta weight was negative, indicating that girls tended to make

better progress than boys. This is frequently the case for verbal tasks.

Biculturality accounted for 3.4 percent of the variance in rate of progress; the beta weight for this variable was positive, indicating that bicultural students tended to make somewhat better progress than monocultural students.

Prior vocabulary level accounted for 7.1 percent of the variance in rate of progress; the beta weight for this variable was positive, indicating that students with initially higher vocabulary levels tended to make better progress.

Therefore it may be concluded that students' rate of progress in a program of individualized instruction in reading comprehension is related to their initial ability in vocabulary but not in reading comprehension, and that this relationship varies with sex, biculturality, and the student's relative initial starting level. These findings are consistent with previous research which stated that prior ability tends to be positively related to subsequent achievement, particularly prior vocabulary ability in predicting reading comprehension. However, with regular instruction, this relationship was much stronger than in the present study; thus, individualized instruction may in fact have reduced the role of prior ability in subsequent learning, equalizing students with differing ability levels. In previous studies, prior reading skills accounted for 36 percent or more of the variance in achievement; in the present study, prior vocabulary ability accounted for only 7 percent and prior reading comprehension skills did not contribute significantly to reading achievement at all.

Figure 4 illustrates the pattern of rate of progress over time for fifth and sixth grade students. This pattern is negatively accelerating and indicates the presence of a "novelty effect" whereby students' gains in

reading tend to be greatest early in the program and to decline over time. There are two possible explanations for this phenomenon. Perhaps students were most interested and involved in the program when it was new, and tended to lose some interest as the novelty of the computer wore off. However, a more likely explanation may lie in the fact that the course material begins at a simple level but becomes progressively more difficult with time, making later gains progressively more difficult to achieve than earlier ones.

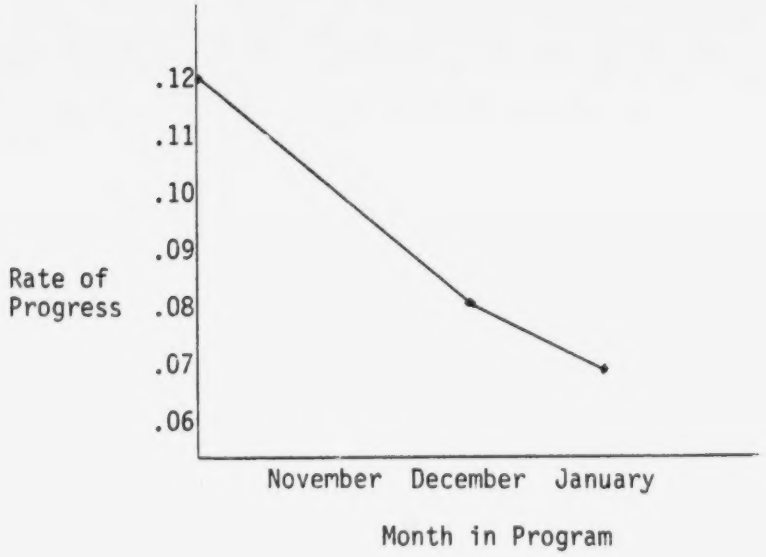


Figure 1

Fifth and Sixth Grade Students' Rate of Progress in Reading Comprehension Over Time

Summary and Conclusions

The research plan adopted in this study included two objectives: a) to understand the nature and extent of intra-individual differences in the development of reading skills; b) to clarify the relationships between rate of progress in reading and verbal ability, gender, and biculturalism. Among our findings, the following specific points are worth retaining because they are applicable beyond a CAI environment:

1. Of the skills that are traditionally assessed in reading comprehension subtests, the most difficult is interpretive comprehension. That is followed by vocabulary and paragraph understanding. Word attack and literal comprehension are the two areas where students show the greatest strength.

2. In terms of responsiveness to individualized instruction, students tend to show the largest gains in academic areas where they have already acquired some strength. The CAI curriculum seems particularly suitable for low-ability students in the areas of literal comprehension and paragraph interpretation. However, one needs to keep in mind that when an instructional program is made uniform for all students, responsiveness signals greater skill mastery but not necessarily greater competitiveness.

3. There is some strong evidence that in order to facilitate the development of reading comprehension, there is an optimal order for introducing and reinforcing the various subskills. The order is as follows: word attack, literal comprehension, vocabulary, interpretive comprehension, and paragraph understanding. In his/her management of the reading class, a teacher is likely to get the best results if time is allocated to each strand in direct proportion of students' needs and of the strand's facilitiative value.

4. Students' rate of progress in reading comprehension is related to their initial starting level, with lower-level students tending to make gains at a slightly faster rate than students beginning at higher levels. This again points to the usefulness of CAI for remedial students in certain areas.

5. Students' rate of progress in reading comprehension bears some relationship to their prior strength in vocabulary skills; students with higher initial ability in this area tended to progress at a faster rate than students with lower initial ability.

6. Students' rate of progress was highest early in the program and tended to decline as their reading level advanced and the curriculum became more difficult.

On a more theoretical level, this study suggests to us two working principles for a better understanding of reading comprehension:

1. The difference between the fully mature reader and the uncertain reader is not just in the ability to combine subskills, but also in their use of the context to derive the meaning of words and sentences.

2. The relationships among the various reading competencies can be explained in terms of two concepts: the level of information-processing which involves either recoding or retrieval, and the level of comprehension which concerns word recognition, denotation or connotation.

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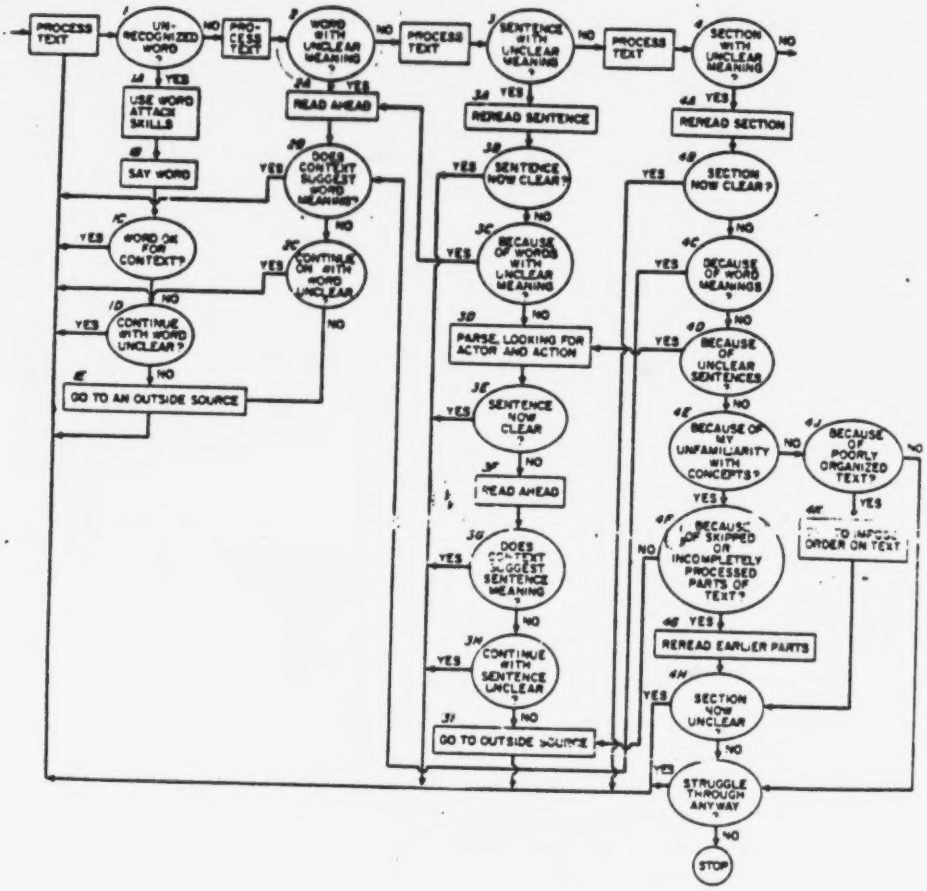

Fig. 7.5. A schematic model of the reading comprehension process.

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APPENDIX F
Companion Study:
The Impact of Computer-Assisted Instruction on Mathematics Learning Gains of Elementary and Secondary Students

Section I

Introduction and Related Literature

A. INTRODUCTION

The concern for competency in mathematics has led mathematics educators in search of trying to unravel the processes underlying the acquisition of various mathematical skills. The consensus which has emerged from these efforts underscores the saliency of four sets of factors: (1) subject variables or the characteristics of the learner; (2) task variables, i.e. the mathematics content problems themselves; (3) process variables - i.e. the cognitive mechanisms students use to solve mathematical problems; and (4) instructional or environmental factors (Lester, 1980).

Of these sets of variables, the greatest attention has focused on instructional or environmental factors. Certainly one has seen within the past twenty years attempts to juxtapose more novel techniques to the conventional strategies of teaching mathematics. In the forefront of these are computer based educational programs.

Increasingly, more and more school districts are opting for this type of instructional strategy in their attempts to improve achievement in the basic skills. Early evaluations of the effectiveness of computer based educational programs have been overwhelmingly positive. However, the nature of the published research has been limited by their minimal attempts to integrate previous findings on mathematics achievement into design paradigms aimed at understanding achievement under computer based instruction.

The typical design paradigm is of an experimental nature in which the performances of students receiving computer assisted instruction are compared to some control group (see Kulik et al 1983 review for example; also Hartley, 1978). Thus, questions regarding the impact of subject and task variables on achievement in computer based educational programs are left relatively unanalyzed.

These questions are, however, quite salient for a number of reasons. First, as a particular mode of instructional strategy, computer assisted instruction may be better suited for the cognitive styles of some students, while not for others. Second, providing information on the relationship between various pertinent variables and mathematics achievement on the computer gives both teachers and administrators useful information with which to plan maximum utilization of the computer. Thus, for example, if particular ability level students tend to derive significantly greater gains on the computer than other ability groups, one might wish to target this group of students for CAI instruction.

Third, information regarding student performance on the mathematical content (task) strands can be very instrumental in helping teachers to more effectively manage learning on the computer. It may be that for content strands on which students are experiencing difficulties in mastery on the computer, teachers would need to reinforce these skills within the classroom lesson.

In approaching this topic, this study took as a conceptual point of departure Lester's (1980) propositions that subject, ability, task, environmental, and process variables impinge on mathematical achievement. These relationships are diagrammed in Figure 1. The underlying premise is that achievement in mathematics can be schematically expressed as a function of the student's social characteristics, and ability, instructional

B. RELATED LITERATURE

The trend towards adopting computer based instruction is rooted both in theoretical as well as programmatic educational foundations. Much of our theoretical insights into the cognitive development of mathematical skills are based on psychological theories, for example, the structuralism of Piaget (1952) and Bruner (1960). Skinner's (1968) notion of operant conditioning, however, has been instrumental in shoring up arguments in favor of programmed learning and computer assisted instruction (Gibb & Lamb, 1975).

Additionally, findings reported by Rosenshine and Furst (1971), as well as Gordon (1971), which highlight the significance of the inclusion in the instructional environment of such attributes as (1) frequent feedback to learners, (2) tutorial relationships, (3) individual pacing, (4) individual programing, (5) clarity of presentation, (6) motivational factors, and (7) task oriented instruction for improving learning, have strengthened the case in favor of computer based education.

Proponents of computer based education have forcibly argued that the computer has the unique ability to incorporate the above attributes. Given its adaptive instructional capabilities, the computer displays versatility in on-line drill and practice, individualized instructional prescriptions, immediate feedback, diagnosis of individual errors and assignment of remediation. In addition to which, the computer has been found to have a positive facilitating effect on student attitude, motivation, and interest in mathematics (Overton, 1981).

From a pragmatic educational viewpoint, computer based education has the advantages of (1) allowing the faculty to teach higher level specialized courses, (2) providing in additional class-time for higher level

instruction by removing basic skill development from the classroom and assigning it to the computer; and (3) providing opportunities for the creative development of innovative curriculum materials (Hall, 1975).

Computer based programs have been extensively used in mathematics instruction. The most widely adopted modes of instructional strategies are drill and practice, and tutorial (Overton, 1981). Drill and practice as an instructional strategy under computer assisted instruction involves student use of the computer to master concepts and techniques that have been learned from other sources. On the other hand, the tutorial mode of instruction involves the presentation of new materials directly from the computer. Students' learning activities are monitored, and, as they progress, more complex tasks are presented.

Evaluation of achievement under both types of instructional strategies seems to indicate that CAI is most effective when used as a drill and practice instructional tool rather than as a tutor. Studies by Cranford (1976), Romero (1979), and Modisett (1980) have unearthed significant positive effects on mathematics achievement for students enrolled in computer drill and practice programs.

Romero (1979), for example, in a study of first and second quartile middle school students, compared regular math instruction with the drill and practice format. Significant differences in achievement between the two groups were found. Students taking drill and practice on the computer performed significantly better on the Metropolitan Achievement Test than students receiving regular math instruction only.

This trend was substantiated by Modisett's (1980) findings on low achieving students in grades 9, 10, and 11. Compared to the workbook,

Modisett found computer assisted instruction as a form of remediation to be far superior. Students belonging to the CAI group showed an average growth in computational skills of 10.5 months of regular schooling as compared to 4.7 months for the workbook students.

The research evidence on the use of the computer as a tutor has been less definitive. Pachter (1979), for example, noted that students who were taught factoring on the computer were more successful in mastering these skills than students taught by conventional methods. However, Eschenburg (1978) obtained mixed achievement results in a study that examined low achieving ninth, tenth, and twelfth grade students using computer supported instruction.

A global picture of the accumulated research evidence on computer based education is provided by the Meta analyses conducted by Kulik et al (1983) and Hartley (1971). The findings, as reported by these authors, for classificatory reasons can be grouped into three areas (1) those related to comparative evidence on the impact of CAI instruction versus non-CAI instruction; (2) those pertaining to grade level effects i.e. elementary versus secondary and (3) those related to the differential impact of CAI on students with different ability levels and socioeconomic backgrounds.

The evidence, as cited in these meta analyses, has been overwhelmingly positive in favor of computer assisted instruction versus regular instruction only. Lysiak et al (1976) looked at the effect of CAI on math and reading achievement for qualifying Chapter I students. Their study showed that students made at least a monthly gain, per month of instruction on the computer curricular. Middle school CAI students made significantly higher standardized test gains than did non-CAI students. Elementary mathematics gains also generally favored CAI students.

In her meta analysis of findings on computer based instruction in mathematics education in elementary and secondary schools, Hartley (1971) reported that the average effect of computer based instruction was to raise student achievement by .41 standard deviations. Elementary students did better with computer based teaching than did secondary students. At the elementary level computer based instruction raised examination scores by .4 standard deviations while at the secondary level, scores were raised by .3 standard deviations.

Kulik et al (1983) noted in their review of the evidence that the effects of computer based teaching appeared to be positive for low aptitude and disadvantaged students. For example, in citing the results of Jamison's, Suppe's and Well's (1974) study, Kulik et al reported that the study found at the elementary levels that computer based teaching, when used as a supplement, had improved achievement scores, especially for disadvantaged students. This finding was supported by Burns and Bozeman (1981) analysis of 40 studies of mathematics achievement which revealed that CAI drill and practice was more beneficial for both disadvantaged and high ability students than for average ability students.

In the more general field of mathematics education a number of research data have burgeoned on such student attribute variables as sex and socioeconomic background. Important empirical strides have also been made in understanding the relative performances of students on the various mathematical content strands.

A number of studies have looked at sex-related differences in mathematics achievement (Stafford, 1972; Sherman, 1977; Fennema, 1974; Fennema and Sherman, 1977; Aiken, 1971, Callahan and Glennon, 1975). Fennema (1974), in a review of 38 studies which looked at sex related differences

and mathematics achievement, reported finding no significant differences between boys or girls mathematics achievement before or during early elementary years. Apparent differences in the upper elementary and high school years were between levels of cognitive tasks. Boys were favored when the tasks were at higher cognitive levels, and girls were favored when the tasks were at lower cognitive levels.

The Coleman report (1966) did much in spearheading a concern with looking at the relationship between socioeconomic background and mathematics achievement. The research evidence garnered seemed to indicate that much of the variance in mathematics achievement appears to be accounted for by socioeconomic factors. Students with high socioeconomic backgrounds tend to achieve better than students from low socioeconomic levels.

The research appertaining to students' performances on the task variables in mathematics suggest that while computational achievement with whole numbers is high, achievement on the content strands of fractions and decimals appears to be problematic (NAEP report 1979). The most problematic mathematical task, however, is problem solving, where test scores tend to be low and where students tend to experience difficulty in applying their computational skills.

In summary, one may state that the research evidence reviewed has been fairly supportive as to the positive impact of computer based instruction in raising mathematics test scores, and in particular, when it is used as a drill and practice instructional tool.

factors such as time on task, the nature of the task, i.e. lower order or higher order mathematical tasks, and processing variables, which include such things as reasoning and the application of various mathematical algorithms etc.

Mathematics Achievement

Instructional Variables	Previous Ability	Processing Factors

Attributes

Figure 1. Model of Mathematics Achievement

The Model above serves as a basis for the following questions:

Research Questions

1. What is the relationship between such attributes as sex, ethnicity, socioeconomic status, ability and mathematics achievement in computer based educational programs?

2. Are there demonstrable differences in mathematics gains that are related to the various content strands?

3. How do such instructional factors as time on task and instructional management impact on achievement?

These questions are answered by looking at the performance of elementary and secondary students enrolled in a drill and practice computer assisted instruction program. Because of the lack of comparability of the mathematic courses in which they were enrolled the analysis was conducted separately for the elementary and secondary schools.

The paper is schematically divided into the following sections. A synopsis of the available research evidence on computer assisted instructions as well as the general findings on mathematics achievement is presented in the second part of this section. A discussion of the findings pertaining to the relationships among the variables at the elementary level is presented in Section II, while section III is devoted to an analysis of the data from the secondary sample.

SECTION II

Elementary Schools

A. METHODLOGY

Eight elementary schools offer CAI instruction. There is much variation from one school to another in that the grade levels using CAI are different, students' ability levels vary, in some schools an aide is assigned to the instruction task, while in other schools a certified teacher works with the children. Some children receive Chapter I services in addition to CAI instruction; others do not. The software programs used are not the same everywhere. All schools do use the Math 1-6 program, but only a few use the Problem Solving program.

The Math 1-6 program is a highly individualized program, tailoring lessons to each student's level, and covering all topics in elementary school mathematics except geometry and word problems. The Problem Solving program is also individualized, and is designed to give students practice in solving word problems.

As indicated in the Introduction, the interest of this study is to ascertain whether the instructional factors, as well as subject factors, such as sex, ethnicity, and ability level are related to CAI mathematics achievement. Further, it is our intention to examine the content strands within the math programs in terms of their level of difficulty as experienced by Newark elementary students. The specific questions which are addressed here are:

1. Are there any variations in total gain scores for the Math 1-6 program by:

   a) ability level
   b) grade level
   c) ethnicity
   d) sex
   e) nature of instruction (teacher or aide)
   f) other services or not (Chapter I or SCE)

2. Are there any variations in the total gain scores for the Problem Solving program by the above six variables?

3. Within the Math 1-6 program, what are the differences in the level of difficulty of the different content strands (e.g. vertical addition, vertical subtraction, equations, etc.) as experienced by Newark elementary students?

4. Are there growth differences by ability level, sex or grade level in the more difficult strands, as well as in the less difficult strands?

A sample of 152 students was drawn. Within the Newark school system, students in grade levels two through eight received CAI instruction. All of the students receiving instruction in the 2nd and 3rd grades who had complete data were included. Those without CTBS scores or those who had not yet been appropriately placed in the Math 1-6 program as of November were excluded. A sample was drawn of 4th, 5th, 6th, and 8th graders who had complete data. All four seventh graders who fit our criteria were included. Table 1 shows the breakdown of the sample by grade level, as well as by sex, ethnicity, whether instructed by aide or teacher, and whether receiving Chapter I/SCE services or not.

In later analyses grades 2 and 3 were combined to form a primary grade level, grades 4, 5, and 6 were combined to form an intermediate level, and grades 7 and 8 were combined to form an advanced level.

Table I

Grade Level, Sex, Ethnic and Instructional
Characteristics of Elementary Student Sample

Grade Level	# of Students	Sex	# of Students	Ethnicity	# of Students	Instruction	# of Students	Receiving Other Services	# of Student
2	28	F	81	Spanish	27	Aide	119	Yes	49
3	30	M	71	Non-Spanish	125	Teacher	33	No	103
4	15								
5	18								
6	39								
7	4								
8	18								

All of the students in the sample were instructed with the use of the Math 1-6 program. Thirty eight students were also using the Problem Solving program. Performance was measured by growth in mathematics achievement from the student's initial placement on the computer until the end of January, 1984. Such growth is generated by computer in the form of a gain score.

As one might suspect, there is a very high correlation between time on task and performance. The relationship between the total amount of time spent on the Math 1-6 program and the total Math 1-6 gain score (indicating the total amount of growth in mathematics achievement) is .70. The correlation between the time spent on the Problem Solving program and the total problem solving gain score is .93. Because of these high correlations, relative gain scores were calculated for each student by dividing the total gain into the total time spent. This solved two problems. One, it controlled for the time-on-task variable, and two, it created an interval scale for performance. (The gain scores are given in terms of grade equivalents, which are not interval scales.) Thus, there were two relative gain scores, math 1-6 gain score and problem solving gain score, which were used as the measures of student performance in subsequent analyses.

A student's ability level was determined by his/her total math score on the Comprehensive Test of Basic Skills (CTBS) administered district-wide in May 1983. Three ability levels were created. Students in the lowest group had normal curve equivalent (NCE) scores of 40 lower. (The cut-off scores for inclusion in the Chapter I program were 42 for grades 2, 7, and 8, 43.6 for grades 4, 5, and 6, and 28 for grade 3.) The middle ability level scored between 41 and 60, and the top ability group scored 61 or more. The number of students in each group was 53, 47 and 50 respectively.

B. RESULTS: SUBJECT AND INSTRUCTIONAL FACTORS

A correlation matrix of all variables is presented in Table II. There is no relationship between the gain scores in Problem Solving and those in Math 1-6 among those students who are being instructed through the use of both programs. As far as the zero order relationships between math performance and the other variables in the study are concerned, there are no significant correlations between achievement in the Math 1-6 program and any other variable, whereas Problem Solving growth is associated with sex, ethnicity and instruction. Boys have higher scores than girls, those of Spanish background have higher scores than others, and those receiving instruction from teachers have higher gains than those receiving instruction from computer aides. An examination of the intercorrelations among the independent variables indicates that there is a very high relationship between ethnicity and instruction (.72), such that those of Spanish background are receiving instruction from a teacher and others are receiving instruction from an aide. Because of this high association and because the number of students of Spanish background is small, as is the number of students receiving help from a teacher, it is impossible in this analysis to ascertain the independent effects of each of these variables.

Sex

Sex is not related to any of the other variables, which means that the difference here is probably real. Boys perform better in the program requiring higher cognitive skills. Although sex and Math 1-6 gain scores were not related in the case of the entire sample, there was some question as to whether there might be variations in the relationships within grade levels. Table III presents the results of t-tests, comparing mean Math 1-6

Table II
Correlation Matrix of all Variables

	1	2	3	4	5	6	7	8
1. Grade Level	1.00							
2. Ability	-.35	1.00						
3. Sex[a]	.03	.05	1.00					
4. Ethnicity[b]	-.11	.13*	-.05	1.00				
5. Instruction[c]	.14*	1.32**	-.01	-.72**	1.00			
6. Other Services[d]	-.41**	.58**	.08	.38**	-.59**	1.00		
7. Math 6 Gain	.02	.12	-.09	.12	-.03	.06	1.00	
8. Problem Solving[e] Gain	-.02	-.01	.31*	-.31*	.29*	.06	-.09	1.00

*$p < .05$
**$p < .001$

[a] female = 1, male = 2 [b] Spanish = 1, other = 2 [c] Aide = 1, Teacher = 2 [d] Other Services = 1, No other services = 2 [e] Number of students using problem solving program is 38

Table III

Results of t-tests
Comparing Male and Female Math 1-6 Gain
Scores within Three Grade Levels

	# of Cases	Mean Score	Standard Deviation	F Value	2-tail Prob.	T Value	2-tail Prob.
Level 1 (Primary)							
Females	33	.17	.20				
				2.95	.088	.76	.45
Males	25	.14	.12				
Level 2 (Intermediate)							
Females	36	.15	.12				
				2.69	.005	1.15	.25
Males	34	.12	.07				
Level 3 (advanced)							
Females	11	.15	.07				
				1.38	.62	.44	.66
Males	11	.14	.08				

gain scores of boys and girls within each of the three grade levels. The t values were not significant at any grade level, indicating that there were no sex differences. One might note, however, that in all cases the girls' scores were slightly higher than the boys. Further, the standard deviations and F values show that there was much greater variation in the scores of girls than of boys at the primary and intermediate levels. Girls did both better and worse than boys. Although the standard deviations decreased from primary to intermediate levels for boys, the decrease was greater for girls and continued through the advanced level.

Ability Level, Grade Level, and Sex

The relationship between ability level and grade level, showing that higher grades have greater proportions of lower ability children, may be confounding the relationships of each of these variables with performance. The relationship between ability level and sex for the entire sample was nil, but within grade levels the relationships varied. At the primary grade level, girls' ability level was higher (-.18). At the intermediate and advanced levels, boys' ability levels were higher (.21 and .28 respectively). The correlations were not high, but each were each greater than the .05 correlation shown in Table II.

The independent effects of sex and ability level on performance were assessed within grade levels through regression analysis. Table IV gives the Beta weights for each variable. Interesting differences occur. At the primary level, higher ability children do better and there are no sex differences. At the intermediate level, although no relationships were significant, the relationship between ability level and performance was positive, i.e., higher ability children had higher gain scores, and girls

Table IV

Regression of Math 1-6 Gain Scores on
Sex and Ability within Grade Levels

	Beta Weights	F Value	N	r^2	F
Primary					
Sex	-.03	.07	58	.11	3.35**
Ability	.32	6.14***			
Intermediate					
Sex	-.17	1.95	70	.05	1.82
Ability	.19	2.46			
Advanced					
Sex	.02	.01	22	.19	2.28
Ability	-.44	4.32*			

*$p < .10$
**$p < .05$
***$p < .01$

scored slightly higher than boys. At the advanced level, the relationship between ability and performance reverses itself. Lower ability children did better. There were no sex differences.

Other Services

In the correlation matrix (Table II) there were significant associations between other services and grade level, ability level, ethnicity and instruction. In two of the schools, the CAI program is part of the Chapter I program and is supervised by a teacher instead of an aide. Both of these schools have large Spanish populations. Grades 2 and 3 are not offered CAI instruction in these schools. Therefore, in order to assess whether CAI students receiving additional Chapter I or SCE assistance perform differently from those who do not, students from only one school were selected. All students in this school are non-Spanish. All CAI instruction is given by a computer aide, and is offered to 6th, 7th, and 8th grade students only. Table V presents the results of the t-test. There is virtually no difference between the two groups. The additional assistance does not seem to have any effect on CAI performance.

Table V

Results of t-test Comparing Mean
Math 1-6 Gain Scores of CAI Students
Receiving Chapter I/SCE Assistance with Those Who Do Not

	# of Cases	Mean Score	Standard Deviation	F Value	2-tail Prob.	T Value	2-tail Prob.
CAI Students Receiving Chapter I/SCE	14	.136	.067	1.58	.430	.02	.986
CAI Students not Receiving Chapter I/SCE	12	.136	.085				

C. RESULTS: MATH 1-6 CONTENT STRANDS

The Math 1-6 program has 14 content strands. Each strand is a series of exercises on the same concept. (see Table VI for a list of the strands and the grade levels that each covers.) The exercises in each strand are grouped into "equivalence classes", each of which is a set of homogeneous exercises. The equivalence classes are arranged in ascending levels of difficulty. When a student masters one class, he/she moves up to the next class. Rates of movement may be different for the different strands - depending on the degree of difficulty of exercises for that particular student.

We wished to ascertain the relative difficulty of the different strands for Newark students. Different strands cover different grade levels, as can be seen in Table VI. Number concepts, equations and measurement cover a wider range of grade levels than other strands. Number concepts and horizontal subtraction begin at grade 1. Fractions and decimals begin at grade 4. The level of difficulty of a strand was assessed by looking at the grade levels at which the strand began, the relative starting points of Newark students in each strand, and the relative gains made in each strand. Here, the gains were determined by the growth which was made in each strand between November, 1983 and the end of January, 1984. In order to determine the relative starting points and the relative gains, the Friedman two-way analysis of variance test, which is a test of mean rankings, was used to see if there were significant differences in rankings among the different strands. A relatively low starting point and a relatively low gain score were indicators of greater difficulty, other things being similar.

Table VI

Strands and Grade Levels
for Math 1-6 CAI Program

Strand	Name	Grade Level
1	Number Concepts	1.0-7.9
2	Horizontal Addition	1.0-4.4
3	Horizontal Subtraction	1.6-4.4
4	Vertical Addition	1.5-5.8
5	Vertical Subtraction	1.6-5.8
6	Equations	2.0-7.9
7	Measurement	2.0-7.8
8	Horizontal Multiplication	2.6-5.8
9	Laws of Arithmetic	3.0-6.8
10	Vertical Multiplication	3.5-7.8
11	Division	3.5-7.8
12	Fractions	4.0-7.9
13	Decimals	4.0-7.9
14	Negative Numbers	6.0-7.9

Primary Level

Students in grades 2 and 3 were being drilled, for the most part, in the first 5 strands. The strands are similar in the sense that the formal starting level for each is in grade 1 and each extends beyond grade 3 (see Table VI). The mean ranks for the actual beginning scores of Newark's primary level students and the mean ranks for their growth scores are presented in Table VII. Horizontal addition is the easiest strand and vertical addition the most difficult of these 5 strands for these students. The starting point is higher and the gains greater in the case of horizontal addition. The exact opposite is true in the case of vertical addition. The differences among the strands were not as great for gain scores as for starting scores. In the latter case, there were substantial intervals between the mean rankings. Regarding gain scores, horizontal subtraction, number concepts and vertical subtraction were similar.

Table VII

Mean Ranks of First Five Strands of Math 1-6
Program: Primary Level Students

Starting Level: Mean Ranks		Gain Scores: Mean Ranks	
Vertical Addition	2.48	Vertical Addition	2.46
Vertical Subtraction	2.79	Horizontal Subtraction	3.00
Number Concepts	2.93	Number Concepts	3.10
Horizontal Subtraction	3.29	Vertical Subtraction	3.13
Horizontal Addition	3.51	Horizontal Addition	3.31

$\chi^2 = 14.55$
$p < .01$

$\chi^2 = 8.83$
$p < .10$

The next step was to look at the relationship between ability and gain scores for each of these strands. The correlation between ability and gain scores in horizontal addition is .37, and between ability and vertical addition is .42. Higher ability students do better in both cases, but especially in the more difficult skill area.

There were no sex differences in either case.

Intermediate/Advanced Levels

Eighty seven students (grades 4-8) were working in the first 8 of the 14 strands. Horizontal addition and subtraction "topped out" at grade level 4.4, meaning that when all items within the strand had been mastered, the student was performing at a 4.4 grade level. Because a number of students did "top out", making it impossible to adequately measure gain scores in these two strands, the two were not included in further analysis. Table VIII presents the mean rankings for starting scores and for gain scores for the remaining six strands. Both equations and measurement had relatively low rankings in start scores and gain scores, indicating greater

Table VIII

Mean Ranks of Start Scores and Gain Scores
in 6 Math 1-6 Strands, N=87, 1=Low, 6=High

Start Scores: Mean Ranks		Gain Scores: Mean Ranks	
Vertical Addition	3.69	Equations	4.12
Equations	3.79	Vertical Subtraction	4.44
Measurement	4.43	Measurement	4.81
Vertical Subtraction	5.09	Horizontal Multiplication	5.05
Number Concepts	5.16	Vertical Addition	5.11
Horizontal Multiplication	5.93	Number Concepts	5.17
$X^2 = 81.9$ $p < .001$		$X^2 = 40.15$ $p < .001$	

difficulty in these skills. Number concepts and horizontal multiplication had higher rankings, indicating that these were easier skills. Vertical addition operated in opposite ways. It was lowest to begin with, but next to the highest in gain score.

Equations and measurement gain scores were combined to form a "high skill" performance dimension, and number concepts and horizontal multiplication were combined to form a "low skill" dimension. They were each regressed on sex and ability. The results are shown in Table IX. None of the relationships were significant. There were no differences in terms of ability level regarding performance on either the high skill or low skill strands. Neither were there significant sex differences. The largest correlation was -.19, indicating that girls may have a slight edge on the high skill strands.

Table IX

Regression of High Skill and Low Skill Gain Scores on Sex and Ability, Grades 4, 5, 6

	Beta Weights	F Value	r2	F
High Skill				
Sex	-.19	3.00	.04	1.70
Ability	-.02	.03		
Low Skill				
Sex	.00	.00	.01	.28
Ability	-.08	.50		

There were 26 sixth to eighth graders who were working in 13 of the 14 strands (only 2 students were working in all 14 strands). According to our criteria of difficulty, fractions, decimals, and equations are considered most difficult and number concepts, laws of arithmatic and division are the least difficult. (See Table X). Difficulty, as experienced by Newark students, is not directly comparable to the ordering of the strands (Table IV). Vertical multiplication, division, fractions and decimals are all skills which begin at grade level 3.5 or 4.0. Yet division is considered one of the least difficult strands by Newark students. It is possible that division is being emphasized in the classroom, whereas equations, fractions, and decimals are not.

Table X

Mean Ranks of Start Scores and Gain Scores
in 11 Math 1-6 Strands: N=26

Start Scores: Mean Ranks		Gain Scores: Mean Ranks	
Fractions	5.86	Decimals	5.65
Decimals	5.86	Horizontal Multiplication	6.15
Equations	5.95	Fractions	6.39
Vertical Multiplication	6.84	Equations	6.65
Vertical Addition	6.91	Vertical Addition	6.69
Horizontal Multiplication	7.38	Vertical Subtraction	6.73
Vertical Subtraction	7.44	Measurement	7.77
Measurement	8.09	Vertical Multiplication	8.44
Laws of Arithmetic	8.45	Number Concepts	8.60
Number Concepts	9.67	Laws of Arithmetic	8.76
Division	11.86	Division	11.48

$X^2 = 137.3$
$p \quad .001$

$X^2 = 105.29$
$p \quad .001$

Fraction, decimal and equation gain scores were combined to form a "high skill" dimension, and number concepts, laws of arithmetic and division gain scores were combined to form a "low skill" dimension. Each of these was regressed on sex and ability (Table XI). The significant relationship was between ability and low skill gains. Those students of lower ability gained significantly more on the low skill strands than did those of higher ability.

Table XI

Regression of High Skill and Low Skill Gain Scores on Sex and Ability; N=26; Grades 6-7-8

	Beta Weights	F Value	r^2	F
High Skill				
Sex	-.08	.13	.11	1.35
Ability	-.27	1.40		
Low Skill				
Sex	.13	.59	.50	11.4*
Ability	-.77	19.56*		

*$p < .01$

D. SUMMARY AND DISCUSSION

The questions addressed at the elementary level were essentially three-fold. How are subject factors and instructional factors related to CAI math performance? Are some content strands within the Math 1-6 program more difficult for Newark students than others? Does performance on the more difficult and less difficult strands vary by subject factors? By answering these questions, we hope that we can provide information that will be useful to those making decisions regarding the uses of computer assisted instruction.

Subject and Instructional Factors

At the primary level (grades 2 and 3), students of higher ability - as determined by total math scores on CTBS - made greater gains on the Math 1-6 program, and particularly on the more difficult content strands. At the intermediate level (grades 4, 5, 6) there were no significant differences in performance by ability, and at the advanced level (grades 7 and 8), the students of lower ability had greater gains, especially on the less difficult content strands. In our sample the ability level of the younger age group is higher than that of the older groups (mean ability level = 2.3, 1.9 and 1.5 respectively for the 3 grade level groups). The fact that within the younger group, the higher ability children do better seems to indicate that there is some minimum level of maturity necessary in order for children to benefit from CAI instruction. Indeed, 2nd graders as a group have the lowest gains of any grade level. While there are some second grade students who do progress in the math program, the majority make minimal gains. It would seem, then, that second graders are probably too young to derive much benefit from CAI instruction. Given the fact that higher ability 3rd grade children benefit and that, as one moves up the

grade levels, lower ability children gain more, computer drill and practice is most helpful to those who are "ahead" when they are beginning learners of certain math skills and those who are "behind" in later grades.

The sex difference which existed indicates that boys do better than girls on the Problem Solving program, confirming the research findings mentioned in Section I that "boys were favored when the tasks were at higher cognitive levels". The converse, that "girls were favored when the tasks were at lower cognitive levels" is not born out here. It is true that the direction of association for most of the relationships between sex and Math 1-6 gains was in favor of the girls (see Tables IV and IX) but none of the relationships was significant. The fact that there was greater variation in the girls scores at the primary and intermediate grade levels and that the tilt in favor of girls at the intermediate level occurred for the high skill strands and not the low skill ones makes one wonder about socialization practices and gender. Perhaps if girls succeed equal to, if not better than, boys on the computer (which does not treat different sexes differently), that will carry over into self images and teacher images regarding sex and mathematics.

No conclusions could be drawn regarding the effects of ethnicity nor of instruction because the two were highly linked. Students of Spanish background were taught by a teacher instead of an aide. This group had higher scores on the Problem Solving program.

Students receiving Chapter I or SCE assistance in addition to CAI performed no differently than students not receiving such assistance. The effects of CAI, then, do not seem to be influenced by what else is going on in the child's life at school.

Math 1-6 Strands

Different mathematics skills are introduced at different grade levels - both on the CAI program and in textbooks - as there is a sequential order in which the different skills are learned. For example, one must know addition and subtraction before one can learn multiplication. Regardless of when a particular skill is introduced, however, there are greater and lesser degrees of complexity - so that one may still be learning addition skills in the 4th grade, even though addition began in grade one.

There are a total of 14 math strands or skills in the Math 1-6 CAI program. For the most part, the difficulty of the skills, as experienced by Newark students, coincides with the ordering by which the skills are introduced, i.e. the more difficult skills are those introduced at a later point in time. There are, however, some exceptions. Division is not introduced until grade level 3.5. Equations and measurement are introduced at grade level 2.0. In terms of difficulty, equations and measurement are considered by Newark students to be considerably more difficult than division. This suggests that there is some disparity between the CAI curriculum and the classroom curriculum in that more classroom time is spent on division than on equations or on measurement. CAI success in these areas would probably be heightened if more classroom time were spent.

Fractions and decimals are introduced later and are considered to be more difficult. There is evidence elsewhere that "math anxiety" begins at this point in the math curriculum (Kogelman and Warren, 1979; Tobias, 1978). It would seem that more time is needed in these areas - not only to enhance these skills, but also to overcome whatever psychological blocks may be contributing to the lack of skill development.

For most of the students in the sample, there were no significant sex or ability differences in "high skill" achievement nor in "low skill" achievement. The exception occurs in the case of upper grade level students (6, 7, 8) who are working in 13 of the 14 skill areas. The lower ability students performed better in the "low skill" area than did higher ability students. This reinforces a point made earlier in this discussion - that for older students, the CAI drill and practice program is very beneficial in helping them to master skills that should have been learned at an earlier point in time, i.e. it is a good remedial tool.

An observation regarding the administration of the CAI program is pertinent to this discussion. In many schools there does not seem to be much coordination of activity between CAI instruction and classroom instruction. The above analysis would suggest that CAI instruction is beneficial for less complex skills, thereby freeing teachers for the instruction of the complex skills.

Section III

The Impact of Computer-Assisted Instruction on the Mathematical Achievement of High School Students

A. INTRODUCTION

The pedagogical benefits of computer assisted instruction as an effective intervention strategy for low achieving mathematical students at the secondary level have been well documented by various researchers. Consistently, it has been shown that students receiving computer instruction, particularly in a drill and practice format, tend to demonstrate significantly better learning gains than students without this assistance.

Indeed, it has been argued that computer assisted instruction is aptly suited for aiding the development of mathematics skills, since mathematics is a hierarchically ordered field in which each skill builds on a foundation provided by lower level skills. While, therefore, there can be no questioning of the beneficial instructional effects of CAI, information pertinent to understanding the nexuses of variables likely to influence mathematics achievement on the computer remains scant.

The conceptual model introduced in Section I, which postulated a set of relationships between subject, task, and instructional variables and mathematics achievement, serves as a reference point for examining these relationships more from a relational than causal perspective among the high school sample. In recaptulating the premises on which the model rests the following propositions may be stated. Mathematical Achievement is a function of the interrelationship between the learner's characteristics

i.e. his sex, socioeconomic background, and previous ability, instructional factors, processing modes and complexity of the mathematical task.

In applying this conceptual scheme to explaining mathematics achievement in computer based educational programs one may ask whether, given the individualized nature of instruction on the computer, one is likely to find the same pattern of relationships. Arguments in favor of the relevance of the model derive from two sources. First, the available literature and evaluation data have been fairly supportive of ability and social background differences in mathematical gains on the computer. Thus, even though the various software computer educational programs do take into account differences in learning aptitude among students, persistent relationships between learner characteristics and mathematical gains do occur. The second and more substantive point is that the computer is an alternative instructional method of presenting and teaching mathematics. Consequently, one can expect that its impact on learning will be somewhat tempered by its degree of congruency with the processing or cognitive styles of the learner.

Research on individualized instruction has indicated that, while some learners do obtain clear learning gains, others experience little or negative learning effects from individualized systems (Glass, 1976; Kulik, 1975). These effects appear to be related to the cognitive style of the students. Thus, some students learn more effectively in a group setting, while others do better in individualized systems.

Having established the relevance of the model, the following research questions generated from the model are studied:

a. What is the relationship between learner characteristics, previous ability and mathematics achievement on the computer?

b. How does computer assisted instruction impact on the development of simple and complex computational skills?

c. How do such instructional factors as time on task, and the instructional management of computer assisted instruction impact on learning gains?

B. METHODOLOGY

The sample consisted of 96 students from grades 9, 10, 11, and 12. These students were receiving computer assisted instruction as a supplement to their regular instruction. Most of the students, based on their standardized achievement test results on the Comprehensive Test of Basic Skills, qualify and in some cases are receiving either Chapter I remedial services, or State Compensatory Education services.

A profile of the sample in terms of demographic attributes indicates that 48 were female, 48 were male. There were sixty three students with English spelling surnames, and 33 with Spanish spelling surnames. Thirty four of the students in the sample attended school in a relatively higher SES neighborhood, and 62 attended schools in poorer neighborhoods.

All students in the sample were enrolled in the course Adult Arithmetic Skills. This course builds proficiency in basic computational skills which students need for both practical and educational reasons. It is a highly individualized course moving students to appropriate levels of difficulty according to a diagnosis of their individual weaknesses and strengths.

The curriculum covers eight mathematical content strands: addition, subtraction, multiplication, division, equations, fractions, measurement, and decimals, with 36 levels of difficulty. However, within each strand there are different difficulty levels. Students work at a particular level of difficulty within a strand until they are answering most of the exercises correctly, then they are moved to the next level.

Operationalization of Variables: Mathematics achievement was operationalized by using the scores for each content strand and course average generated by the computer for the end of November and end of January. In the first set of data analysis learning gains were arrived at by taking the difference between the course averages for the end of November and end of January. The analysis of achievement on the content strands (see Section C) was approached from a different perspective.

Within each content strand, there are a number of items with different levels of difficulties. Thus, for example, on the addition strand there are 25 levels of difficulties and for subtraction 24. These levels of difficulties were treated as mastery objectives. The levels on which students were working for each of the individual strands were expressed as a percentage of the total number of objectives or levels for that strand. Thus for example, if a student on the subtraction strand was receiving items on level 12, this was translated to mean that he has mastered 50 percent of the objectives for this strand.

Students' previous mathematics ability was determined by using their performance on the two subtests of the Comprehensive test of Basic Skills: computation, and concepts and application. Whether students were classified as being mono or bicultural was based on their names. The socioecology of the school was arrived at by using information based on the number of families in the attendant neighborhood eligible to receive AFDC.

Statistical Analysis - Multiple regression procedures were used to estimate the relationships between student characteristics, previous mathematic achievement and learning gains demonstrated on the computer. Analysis of performances on the content strands relied on the application of nonparametric techniques. Wilcoxon matched sample tests were used to

determine whether there was any significant improvement on each of the content strands between the months of November and January. Spearman Rank Correlation (rho) was employed to measure the relationship between performance on the content strands and various learners' characteristics. Assessment of the impact of time on task and instructional management on mathematic achievement was arrived at through the use of linear flow graph techniques.

C. THE RELATIONSHIP BETWEEN LEARNER CHARACTERISTICS, PREVIOUS ABILITY AND MATHEMATICS ACHIEVEMENT ON THE COMPUTER

Bloom (1982), on the basis of the various empirical findings on school learning, developed a model in which any learning outcome could be explained by the interrelationship between students entry characteristics and the quality of instruction. The theoretical formulation on which the model is premised is that the history of a learner as subsumed by cognitive and affective entry behaviors is at the core of learning. This formulation is in agreement with Lester's (1980) findings regarding achievement in mathematics and, thus, provides us with a theoretical justification for exploring the relationships between learner characteristics, cognitive entry factors, and achievement.

Studies that have explicitly examined the relationships between learner characteristics, cognitive entry behaviors and mathematics achievement on the computer have yielded interesting findings. Previous mathematical ability and the social background of the student have been found to be consistently related to achievement in computer based educational programs. The direction of the relationships implied that lower mathematical

ability students as well as students from more disadvantaged social backgrounds were likely to derive greater learning gains than high ability students and students with better socioeconomic backgrounds.

These findings are opposite to those in the field of mathematical education focusing on conventional teaching strategies. The general trend that has burgeoned is for high ability students and higher SES students to be more proficient in mathematics.

In unraveling the relationship between these three sets of variables in this study the following analytic strategy was pursued. First, the relationship between students' characteristics, i.e. sex, ethnicity, and socioeconomic status and previous ability was established. Second, the extent to which these variables were related to learning gains on the computer was examined.

Our first line of analysis indicates that sex and the socioeconomic context of the school are factors that influenced the cognitive entry characteristics of students in the study on both indices of previous mathematical achievement (see Table XII). The direction of gender differences suggested that girls were less deficient in these skills than were boys. This finding was not surprising. Previous studies conducted on the remedial population in this school district have evinced similar patterns of results (Madhere and Walker, 1983). There were, however, no ethnic differences in the previous mathematical performance of students.

Of noteworthy interest was the significance of the socioeconomic context of the school as a predictor of student cognitive entry characteristics. The direction of association between the variables implied that students attending schools in poorer neighborhoods had higher mathematical ability levels. In ascertaining whether this finding was sample specific

Table XII

Zero Order Correlation Coefficients Representing the Relationship Between Sex, Ethnicity, Social Ecology of the School, Computational Achievement, Achievement in Concept and Application And Achievement on the Computer

	Computational Achievement	Achievement Concepts & Application	Achievement on the Computer	Sex	Ethnicity	Social Ecology of the School
Computational Achievement	1.00					
Achievement in Concepts & Applications	.60*	1.00				
Achievement on the Computer	.02	.06	1.00			
Sex	-.28*	-.28*	.03	1.00		
Ethnicity	-.01	.02	.27*	-.24	1.00	
Social Ecology of the School	.30*	.18*	.24*	.13	-.56*	1.00

*Significant at .01

or true of the population, we looked at the overall academic performance in mathematics for the schools in the sample, and found that in actuality the schools in the "better socioeconomic neighborhoods" had higher mathematical achievement levels. This led us to speculate that this finding was probably an artifact of the selection procedures used to place students on the computer. A cursory examination of the scores indicated that in schools located in poorer neighborhoods there were students receiving computer assisted instruction under the remedial component with scores higher than the State Minimum level of proficiency.

The relative predictive power of previous mathematical achievement and learner characteristics in explaining learning gains on the computer can be gleaned from Table XIII. A number of interesting findings are apparent. Students' cognitive entry characteristics as measured by previous mathematical performance in concept and application and computation are not significant in predicting the learning gains that students experience on the computer.

This clearly augurs well for computer assisted instruction. The implication being that instruction under this program is having beneficial learning effects for all ability level students. Thus, in maximizing individualized instruction, the computer is able to obviate any impact that previous ability might have had on mathematical learning outcomes.

Table XIII

Regression Results with Dependent Variables, Previous Achievement in Computation and Concepts and Application and Predictor Variables, Sex, Ethnicity and the Socioecology of the School

	Computation			Concept & Application		
Predictor	Beta	F Value	Square	Beta	F Value	R Square
Sex	-0.30	9.25*	0.09	-0.29	8.09*	0.08
Ethnicity	0.12	1.13	0.01	0.10	0.74	0.01
Socioecology of School	0.40	12.804*	0.16	0.29	8.09*	0.08

*Significant at .01

Both sex and the socioeconomic context of the school were also non-significant predictors. Similar arguments can also be posited for these variables. The only significant predictor was ethnicity. Computer assisted instruction under this drill and practice program was more effective in raising the learning gains of bicultural than monocultural students.

While there have been few studies comparing the impact of computer assisted instruction on the learning outcomes for different ethnic groups, extensive analysis of its impact on the bilingual population has been done (Saracho, 1982a and 1982b). These studies have shown that CAI tended to have a positive effect on learning for these students. Within the context of this study the differential impact of CAI on the learning gains of monocultural and bilingual high school students however may be partially explained by a factor which may be called computer familiarity.

Table XIV

Regression Results with Dependent Variable, Learning Gains on the Computer and Predictor Variables, Prior Computational Skill Achievement, Previous Achievement in Concept and Application, Sex, Ethnicity and the Socioeconomic Context of the School

Predictors	Beta	F Value	R Square
Prior Computational Achievement	0.18	1.438	0.03
Previous Achievement in Concept & Application	-0.11	0.768	0.01
Sex	0.14	1.639	0.02
Ethnicity	0.24	3.984*	0.06
Socio-economic context of School	-0.15	1.438	0.02

* Significant at .05

Computer assisted instruction in this school district was implemented as an aide for the bilingual student population. These students, therefore, have spent longer hours and consequently have developed a greater degree of familiarity with the computer than monolingual students. As a novel form of instructional strategy, one can expect that there is a period of adjustment to the computer. While other course packages allow for this period of adjustment, the Adult Arithmatic Skill course, does not; therefore, differences which we are finding between the ethnic groups may be reflecting factors related to student adjustment to the computer.

The accumulated impact of these pre-entry variables on students' mathematics gain is relatively marginal, with these variables accounting for 14 percent of the variance in mathematics achievement. These findings underscore some of the theoretical work that has been done on mastery learning. (See Bloom, 1983, Carroll, 1963). (Individualized Computer programs are structured around a mastery concept of learning). Carroll (1963) has posited that learners will succeed in mastering a given task to the extent that they received quality instruction and that they spend the amount of time on the task that they individually need to learn it. Thus, initial differences among learners will not be reflected in final differences in achievement, though the time that students need for mastery will vary.

D. STUDENTS' PERFORMANCE ON THE MATHEMATICS CONTENT STRANDS

The previous analysis focussed on students' overall academic performance in mathematics on the computer, without looking at differences in mastery levels for the various mathematical tasks. Mathematics achievement is, however, not a unitary phenomenon. The available body of research indicates quite strongly that achievement in mathematics is largely dependent on the nature of the mathematical task. Further, various types of cognitive models can be used to explain the development of various mathematical skills.

Many low level skills in arithmetic (for example, simple addition, subtraction and multiplication) can best be explained in terms of mechanistic models, while more complex arithmetic and problem solving skills lend themselves to an organismic analysis (Carpenter, 1980). The difference between both types of models pivots around the complexity of the cognitive processes involved. Given the nature of the drill and practice format of the adult arithmetic skills course, one can hypothesize that improvement in mathematics competency for the lower level computational skills is likely to occur at a greater rate than the more complex computational skills.

With this hypothesis as a conceptual guiding point, three lines of inquiry pertaining to the impact of computer assisted instruction on the development of proficiency in simple and complex computational skills were initiated. First, we attempted to estimate the degree of skill deficiency that learners were experiencing on entering the program by comparing their pretest means for each mathematic skill. Second, the relative impact of computer assisted instruction on each skill area was arrived at by

comparing the relative learning gains demonstrated by students in these areas. Third, the extent to which CAI helped particular learners in the development of simple and complex mathematical skills was determined by looking at the Spearman rank correlations between mastery of simple and complex computational skills and various learner's characteristics.

Table XV presents information pertinent to answering the first question. Observations of the pretest means indicate not surprisingly that students are experiencing the greatest difficulties in mastering the more complex computational skills. Indeed, the pattern evident in the table is for mastery to decline as the skill becomes more complex. (Although the pretest mean for the measurement skill was relatively high, only a few students had reached a level of mastery in the other skill areas to be eligible to receive problems on this strand).

Comparison of the postest means with the pretest means and the Wilcoxon z values reported indicate that students have made significant positive learning gains in all of the 7 mathematical content areas.

Table XV
Pretest and Posttest Means, Standard Deviations
and Wilcoxon z Values for the Mathematic Content Strands

Content Strand	Mean	Standard Deviation	Mean	Standard Deviation	Change	Wilcoxon z Value
Addition	66.405	21.851	84.372	22.576	18.967	6.494*
Subtraction	59.044	17.460	72.087	21.466	13.043	6.698*
Multiplication	57.593	18.513	69.100	21.914	11.507	5.991*
Division	57.048	16.438	63.875	18.541	6.827	4.456*
Equation	47.840	8.936	52.757	15.626	4.917	4.258*
Fraction	54.273	6.526	58.778	14.513	4.505	3.351*
Measurement	73.682	12.167	76.143	17.490	2.461	2.187**

*Significant at .01
**Significant at .05

However, although CAI has had a facilitating effect in minimizing mathematical deficiencies on each of the content strands, the rate of mastery differs. It is obvious from the table that the more immediate impact of the program is on the lower computational skills. Thus, students have made the clearest gains in addition and subtraction and multiplication. The rate of progress is, however, slowed for the more complex computational strands, for example, equations, fractions and measurement.

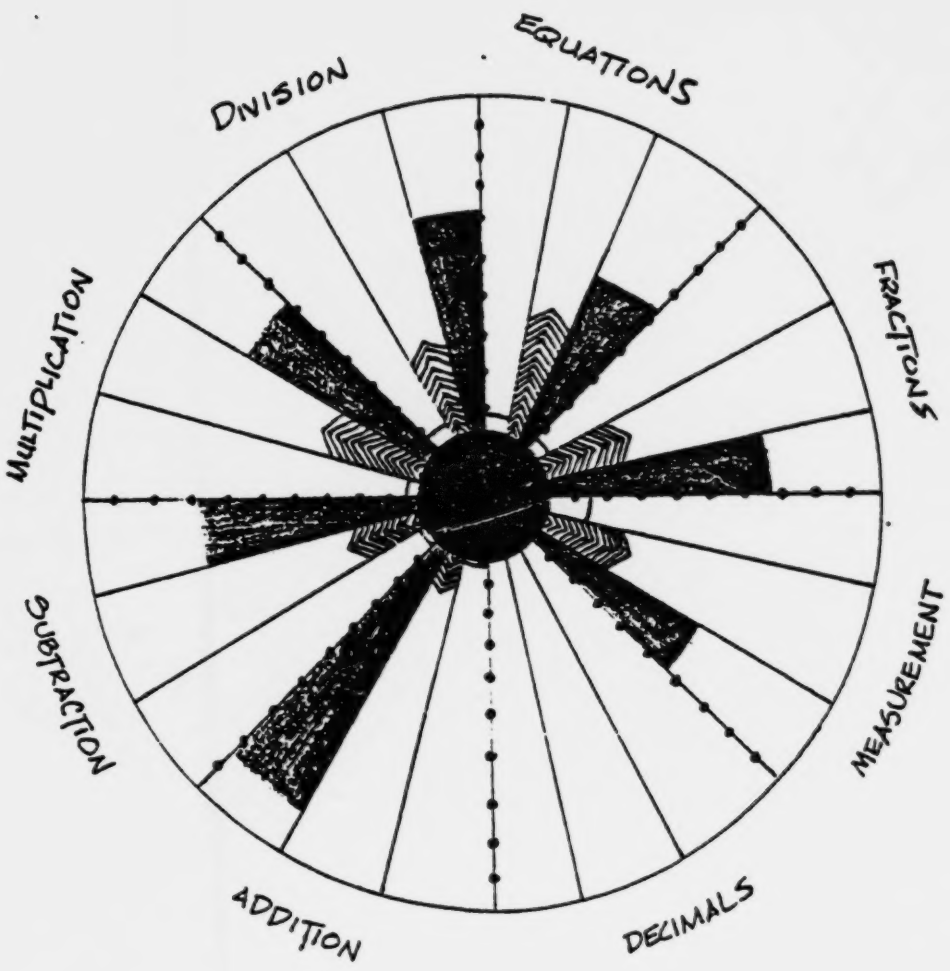
An alternative presentation of this information can be found in the chart on page 47. The chart provides three pieces of information for each of the skill areas. First, it gives the percentage of students who were able to increase their mastery of the more difficult items over the pretest. The second percentage given is the number of students who are working on problems at the same level of difficulty and the third set of information pertains to the percentage of students whose mastery levels have actually fallen below their starting level in the program.

As is evident from Figure 2, the skill areas of measurement and equations are the most problematic. For equations, only 52 percent of the students were able to increase their mastery of the more difficult items for this skill, 40 percent remained at the same level of difficulty and 8 percent declined. On the measurement strand, while 57 percent improved their mastery levels, 29 percent remained at the same difficulty level and 14 percent declined.

Figure 2

PIE CHART OF STUDENT PROGRESS ON EACH

OF THE MATHEMATICS STRANDS



Increased Mastery

Remained at Same Level of Mastery

Decreased Mastery Level

• Represents Ten Percent (10%)

The percentages reported for students who have increased their mastery or who have remained at the same levels in these skill areas underscore the general conclusion that longer time is needed to master these more difficult skills. However, the information presented on those who have actually fallen below their initial level is of some concern. This suggests that students were either started at too high a level on this skill, or alternatively, that the basic mathematical algorithms for this skill are not being learned, hence, students are experiencing difficulties in transfering their knowledge on the simple items to solving more complex tasks.

For those students who are missing all items at a particular level, project teachers may want to initiate fixed drills on these skills, so as to give these students sufficient practice in these areas. Further, the information presented in Table XV and Figure 2 may be quite useful to those project teachers who have students in CAI. For one, the fairly strong impact of CAI on simple computational skills suggests that project teachers may want to devote proportionately more time to teaching the more complex skills such as equations, fractions and measurement which are not as easily malleable to change. Alternate instructional strategies such as workbook activities may also be useful in supplementing computer instruction in these skill areas.

Since we know that the computer is having a differential impact on improving skill competency for the simple and more complex computational skills, of interest was seeing which students the computer was helping in which sets of skills. For the purpose of this analysis, a dichotomy was employed, where addition, subtraction and multiplication were combined and taken to represent lower mathematical skills, and equations, fractions and

measurement were grouped as representing more complex arithmetic skills. A series of Spearman rank correlation coefficients (rho) were computed in order to see the relationship between the development of skill competency for the simpler and more difficult tasks and certain student characteristics.

The correlation coeficients reported in Table XVI reflect a number of interesting relationships. Firstly, the correlation between mastery of simple and mastery of more advanced computational skills implies that

Table XVI

Spearman Rank Correlation Coefficients Representing Relationships Between Mastery of Simple and Difficult Computational Skills and Selected Student Characteristics

	X1	X2	X3	X4	X5	X6	X7
Mastery of Simple Computation Skills (X1)	1.00						
Mastery of Advanced Computational Skills (X2	0.67**	1.00					
Sex (X3	0.09	-0.32	1.00				
Ethnicity (X4)	0.27*	0.66*	-0.28	1.00			
Achievement on CTBS Concept & Application (X5)	0.01	-0.43**	0.31	0.03	1.00		
Achievement on CTBS Computation (X6)	-0.03	0.06	0.26	0.03	0.61*	1.00	
Socioeconomic Characteristic of School (X7)	-0.32*	0.81*	0.13	-0.56*	0.18	0.27*	1.00

*Statistically Significant at .01
**Statistically Significant at .05

students who are successfully mastering the simple computational skills are also doing well on the more complex tasks. However, the less than perfect correlation suggests that acquisition of simple computational skills, though necessary prerequisites, are not the only skills necessary for successfully mastering the more difficult skills.

Bicultural students appear to have been helped significantly on both sets of skills, though the strength of the relationship suggests a stronger relationship with the more complex skills. This finding certainly serves to substantiate the thesis that the more difficult skills require a longer period of time for mastery, since, as was previously cited, these students have spent a longer time on the computer than monolingual students.

While computer assisted instruction is helping all ability range students (as measured by past performance on the CTBS concepts and application and computation) in the development of addition, subtraction, and multiplication competencies, on the more advanced arithmetic skills (fractions, measurement and equations) the lower ability students are being helped more ($r=-.43$).

E. THE IMPACT OF TIME ON TASK AND INSTRUCTIONAL MANAGEMENT ON ACHIEVEMENT

Two critical instructional factors that have been found to be highly correlated with achievement are "teacher competency" and "student engaged time". It is instructive to note that the research on learning outcomes has shown that the impact of any instructional program or innovation on pupil achievement can be stymied or enhanced by the quality of the instructional management (Mitzel, 1960; Medley, 1982). Indeed the results of several process - product studies have schematically presented learning outcomes to be influenced by teacher competency, teacher performance, and pupil learning experiences (Mitzel, 1960; Medley, 1975).

The second important variables "student-engaged time", concerns the extent to which students are actively involved in learning. The substantive findings in the literature underscores the saliency of time on task as a discriminating factor in explaining achievement.

The extent to which these two factors had explanatory significance in accounting for the differences in mathematics achievement in this sample was explored. In our sample of students thirty five were receiving computer assisted instruction supervised by a teacher's aide while sixty one were being supervised by a remedial math specialist. Whether this factor, as well as the time spent on task, made a difference in the learning gains students derived from computer assisted instruction was determined by the use of linear flow graphs. This technique is extremely useful for understanding the relationship between categorical variables, particularly when one is interested in decomposing inferred change in a dependent variable (Davis, 1976).

For the purpose of this analysis, student mathematics achievement was dichotomized into high and low. This dichotomization was based on whether students had increased the levels of difficulty for their course average by 4. Since there are 36 levels of difficulty on the Adult Arithmetic course, it was estimated that a change of 4 would represent a month's gain. Thus, students who had changes of less than 4 were classified as low achievers, and those with a month or more gain were classified as high achievers. Similar techniques were used for the time on task variable. This variable was dichotomized as low time on task or high time on task through the use of a median split. Students who spent less than 148 minutes on the terminal were classified as having low time on task, and conversely those who had spent 148 minutes or more were classified as having high time on task.

The relationship between the instructional management of the program and achievement can be gleaned from Table XVII and Figure 3. The conditional proportions in the table reflect that proportionately more students being supervised by trained teachers have experienced high achievement (.475) than those being supervised by an aide (.114). The difference between the two proportions is .36 in favor of project teachers. One may interpret this difference as implying that if one were to shift from having the program being supervised by an aide to a project teacher that one would increase the number of students having high achievement gains by 36 percent. (This relationship is graphed in Figure 3)

Table XVII

Relationship Between Instructional Management and Mathematic Achievement

Instructional Manager	Achievement		
	Low Achievement	High Achievement	
Project Teacher	32	(.475) 29	61 (.635)
Teacher Aide	31	(.114) 4	35 (.364)
Totals	63	33	96

a=.36
High Achievement=(.360 x .635 + .114 = .34

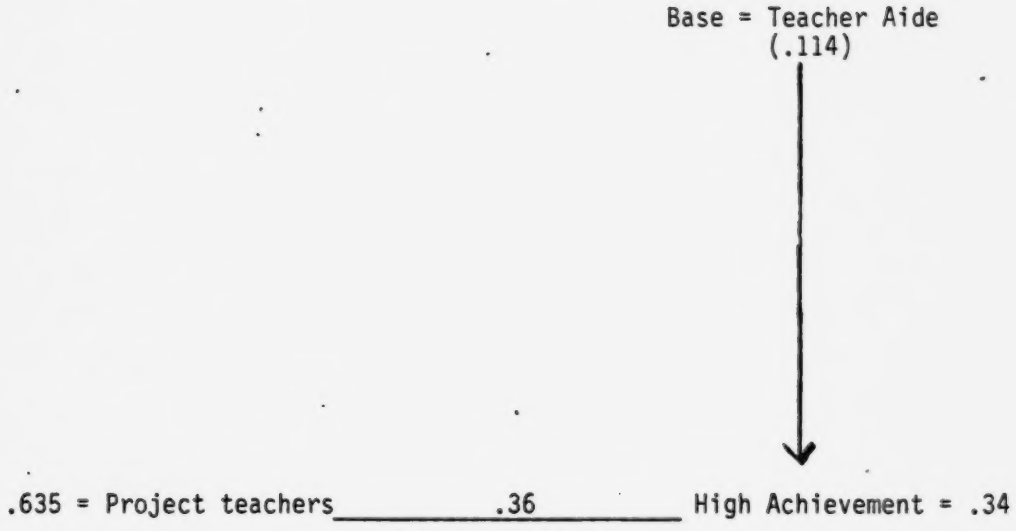


Figure 3: Flow Graph of Relationship Between Instructional Management and High Mathematic Achievement

The association between time on task and mathematics achievement is illuminated in Tables XVIII and Figure 4. As is starkly evident from the table, learning gains on the computer are closely related to time on task. Approximately half the students with high time on task experienced a month or more learning gain (.527). If one takes the difference between this proportion (.527) and the proportion of those students with low time on task and similar learning gains (.0974) one gets a value of .429. This may be interpreted as meaning that by simply increasing students time on task from less than 148 minutes to more than 148 minutes or from low to high, one would increase the proportion of students with high learning gains by 43 percent.

Table XVIII

The Relationship Between Time on Task
and Mathematics Achievement

Time on Task	Achievement		
	Low Achievement	High Achievement	
High time on task	26	(.527) 29	55 (.573)
Low time on task	37	(.097) 4	41 (.427)
Totals	63	33	96

a=.429
High Achievement=(.429 x .573 + .097 = .34

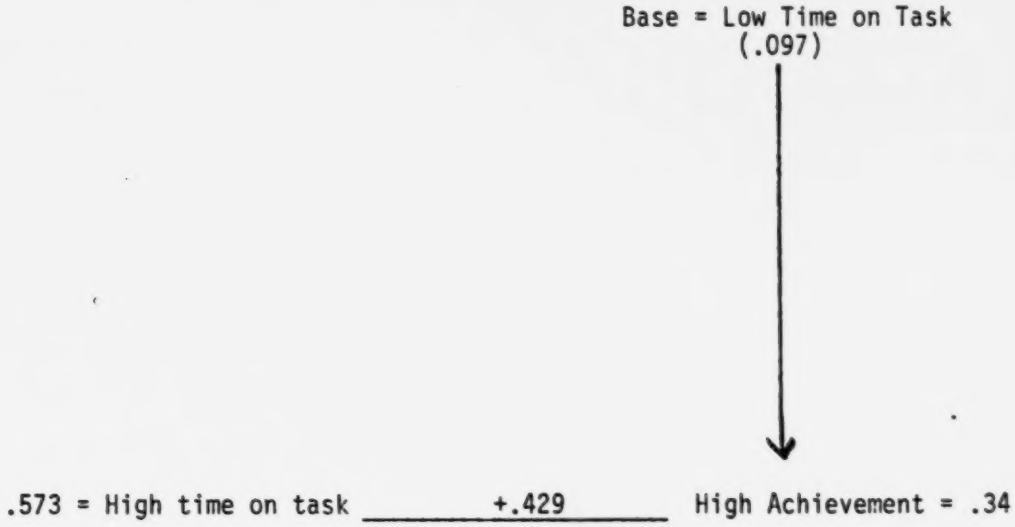


Figure 4: Flow Graph of Relationship Between Time
on Task and High Mathematics Achievement

A comparison of the relative weights associated with the d values for time on task and instructional management suggests that of the two instructional variables, time on task has the most important impact on mathematics achievement.

Discussion

The preceeding analyses of high school students' achievement on the computer have afforded us some insight into the factors that are related to mathematics achievement on the computer. A number of implications loom large.

First, the findings which have clustered around the neglible effects of previous academic as well other non-instructional differences (eg sex) on learning outcomes in the CAI program highlight the importance of the mastery concept of learning especially with remedial populations. It is patently clear that when instruction is tailored to meet the individual student's need, and when there is consistency in the quality of the instruction to which all learners are exposed, differences due to noninstructional factors between learners are, if not totally obviated, at least minimized.

Second, the information generated by this study on the mathematics content strands points us in some useful directions in terms of the alignment of the instructional activities within the classroom and instruction on the computer. The richness of the information provided by the computer on the content strands can be used by remedial math teachers for both diagnostic as well as teaching purposes. Further, the differential impact of the computer in remediating dificiencies for simple as well as more difficult mathematical skills suggests that one way of maximizing the benifits that students receive from remediation is to

allocate the remediation of simple computational skills to the computer, while project teachers focus their efforts on dealing with the more complex mathematical skills.

Third, the impact of instructional management on student achievement in the program is highly suggestive of the need for there to be continuity in the instructional interaction between teachers and students while students are on the computer. Although the computer provides immediate feedback, the quality of that feedback is extremely limited. Students are not told why they are getting a problem incorrect by the computer. This has serious implications when one starts to address the issue of retention effects of computer assisted instruction - a question which appears to have no definitive answers when one review the studies that have been done on this topic. In fact Kulik (1983) has noted in a review of five studies on this issue that the retention effects of CAI were not statistically significant, and in one case were higher for students not in the CAI program.

RECOMMENDATIONS

Based on the foregoing analysis of Computer Assisted Instruction, we offer the following recommendations:

1. The coordination of instruction between the classroom and the computer program should be improved. Students would benefit if their strengths and weaknesses were dealt with in both places in a concerted effort.

2. Given that some skills are considered by Newark students, to be more difficult than others, more time - more computer time and more classroom time - should be spent on these skills. Specifically, the more difficult skills are equations, measurement, fractions and decimals.

3. Second graders as a group seem to be too young to benefit greatly from CAI instruction, and higher ability third graders benefit more than lower ability ones. This suggests that second graders and lower ability third graders should probably <u>not</u> be instructed in math through CAI.

4. Whatever differences in performance that were found at the upper elementary and high school levels were in favor of lower ability students; thus, CAI seems to be a good remedial tool.

5. Teachers should <u>supervise</u> students on CAI. The computer does not tell a student why a mistake was made. Students benefit more when there is a dialogue between teachers and students.

6. Although boys did do better in problem solving skills (used only by upper elementary students), girls did as well as, if not better than boys in all other skills. Computers do not differentiate between sexes. This should be a lesson for teachers and for girls, themselves. Math proficiency is probably not biologically predetermined.

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